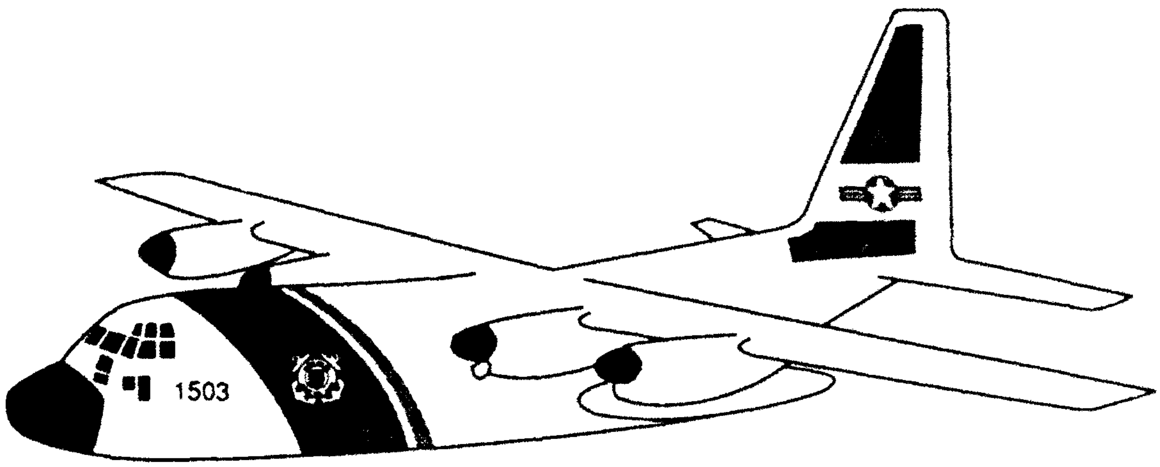
U. S. Department of Transportation
United States Coast Guard

200 Years of Service

Report of the International Ice Patrol in the North Atlantic



HC-130 AIRCRAFT
25 years of Ice Patrol Service

1988 Season
Bulletin No. 74
CG-188-43

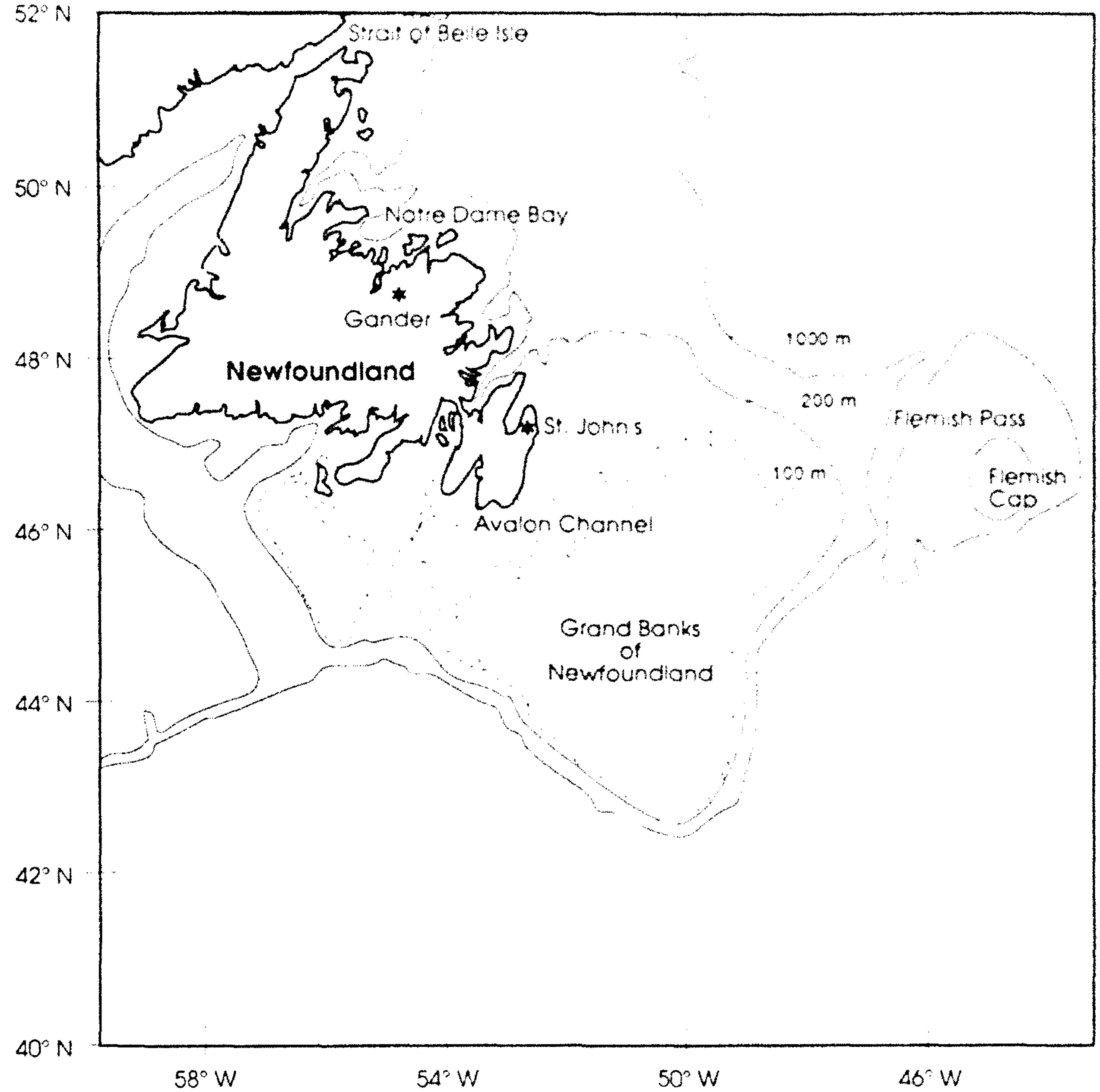


Figure 1. Bathymetry of the Grand Banks of Newfoundland.

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Bulletin No. 74

REPORT OF THE INTERNATIONAL ICE PATROL IN THE NORTH ATLANTIC

SEASON OF 1988

CG-188-43

FOREWORD

Forwarded herewith is bulletin No. 74 of the International Ice Patrol, describing the Patrol's services, ice observations and conditions during the 1988 season.

JWLockwood, Acting

J. W. LOCKWOOD
Captain, U.S. Coast Guard
Acting Chief, Office of Navigation
Safety and Waterway Services

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INTERNATIONAL ICE PATROL 1988 ANNUAL REPORT

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APPENDICES

Introduction

This is the 74th annual report of the International Ice Patrol Service in the North Atlantic. This report contains information on Ice Patrol operations, environmental conditions, and ice conditions for 1988. The U.S. Coast Guard conducts the International Ice Patrol Service in the North Atlantic under the provisions of U.S. Code, Title 46, Sections 738, 738a through 738d, and the International Convention for the Safety of Life at Sea (SOLAS), 1974, regulations 5-8. This service was initiated shortly after the sinking of the RMS TITANIC on April 15, 1912.

Commander, International Ice Patrol, working under Commander, Coast Guard Atlantic Area, directs the International Ice Patrol from offices located at Groton, Connecticut. The International Ice Patrol analyzes ice and environmental data, prepares the daily ice bulletins and facsimile charts, and replies to any requests for special ice information. It also controls the aerial Ice Reconnaissance Detachment and any surface patrol cutters when assigned, both of which patrol the southeastern, southern, and southwestern limits of the Grand Banks of Newfoundland for icebergs. The International Ice Patrol makes twice-daily radio broadcasts to warn mariners of the limits of iceberg distribution.

Vice Admiral D. C. Thompson was Commander, Atlantic Area, until June 29, 1988, and Rear Admiral J. C. Irwin was Commander, Atlantic Area, from June 29, 1988, to the end of the 1988 ice year. CDR S. R. Osmer was Commander, International Ice Patrol, during the entire 1988 ice year.

Summary of Operations, 1988

From April 13 to August 2, 1988, the International Ice Patrol (IIP), a unit of the U.S. Coast Guard, conducted the International Ice Patrol Service, which has been provided annually since the sinking of the RMS TITANIC on April 15, 1912. During past years, Coast Guard ships and/or aircraft have been patrolling the shipping lanes off Newfoundland within the area delineated by 40°N - 52°N, 39°W - 57°W (Figure 1, inside front cover), detecting icebergs, and warning mariners of these hazards. During 1988, Coast Guard HC-130 aircraft flew 40 ice reconnaissance sorties, logging over 257 flight hours. The AN/APS-135 Side-Looking Airborne Radar (SLAR), which was introduced into Ice Patrol duty during the 1983 season, again proved to be an excellent all-weather tool for the detection of both icebergs and sea ice. In addition, the AN/APS-131 SLAR on the Coast Guard HU-25B aircraft was evaluated, and the HU-25B was used operationally for the first time on one ice reconnaissance sortie.

Aircraft deployments were made on February 17 to 21, March 3 to 16, and March 28 to April 1 to determine the pre-season iceberg distribution. Based on the last pre-season deployment, the 1988 International Ice Patrol season opened on April 13. From this date until August 3, 1988, an aerial Iceberg Reconnaissance Detachment (ICERECDET) operated from Gander, Newfoundland, one week out of every two. The season officially closed on August 2, 1988.

Watchstanders at IIP's Operations Center in Groton, Connecticut, analyze the iceberg sighting information from the ICERECDET, along with sighting information from commercial shipping and Atmospheric Environment Service (AES) of Canada sea ice/iceberg reconnaissance flights. The IIP Operations Center received 35,129 iceberg sightings from these sources in 1988, compared to 7,031 in 1987. Only those iceberg sightings within IIP's operations area (40°N - 52°N, 39°W - 57°W) are entered into the IIP iceberg drift prediction computer model (ICEPLOT). The watchstanders determine whether the sighting is a resight of an iceberg IIP already has on ICEPLOT, or whether the sighting is of a new iceberg which had not been previously reported. Iceberg sightings near the Newfoundland coast are not entered into the computer model due to lack of ocean current information in the model in these areas to drift the icebergs. Each sighting is labelled in the computer as either a resight or a new sighting. During the 1988 ice year, an estimated 1340 icebergs were sighted in IIP's operations area (south of 52°N), compared to 755 in 1987. 1160 of these were entered into IIP's computer model, compared to 686 in 1987.

IIP's computer model consists of a routine which predicts the drift of each iceberg, and a routine which predicts the deterioration of each iceberg. The drift prediction program uses a historical current file to drift the icebergs. This historical data file is modified weekly using satellite-tracked ocean drifting buoy data to take into account local, short-term current fluctuations. Murphy and Anderson (1985) describe the IIP drift model in more detail, along with an evaluation of the model.

The IIP iceberg deterioration program uses daily wind, sea surface temperature, and wave height information from the U.S. Navy Fleet Numerical Oceanography Center (FNOC) to melt the icebergs. Appendix C discusses recent improvements FNOC has made to these products. Anderson (1983) and Hanson (1987) describe the IIP deterioration model in detail. It is the combined ability of the SLAR to detect icebergs in all weather, and the IIP's computer models to estimate iceberg drift and deterioration, which has enabled IIP to reduce its ICERECDET operations from weekly deployments to every other week deployments.

Table 1. Source of International Ice Patrol Iceberg Reports by Size.

Sighting Source	Growler	Small	Medium	Large	Radar Target	Total	Percent of Total
Coast Guard (IIP)	43	315	289	168	39	854	39.0
Canadian AES	17	210	268	115	28	638	29.2
Commercial Ship	37	76	266	78	44	501	22.9
Offshore Oil Industry	6	42	51	31	1	131	6.0
Lighthouse/Shore	0	1	10	6	0	17	0.8
DOD Sources	0	1	8	6	0	15	0.7
Other	0	3	11	3	13	30	1.4
Total	103	648	903	407	125	2186	100.0

Table 1 shows the total iceberg sightings reported to IIP in 1988 (including resights) which were in IIP's operations area and away from the Newfoundland coast, broken down by the sighting source and iceberg size. IIP ICERECDET, AES, and commercial shipping continue to be the three major sources of iceberg sighting reports. Appendix A lists all iceberg sightings received from commercial shipping, regardless of the sighting location.

Table 2 lists monthly estimates of the total number of icebergs that crossed 48°N for the pre-International Ice Patrol era, and for the ship, aircraft visual, and aircraft SLAR reconnaissance eras. Table 3 compares the estimated number of icebergs crossing 48°N for each month of 1988 with the monthly mean number of icebergs crossing 48°N for each of the four different eras.

During the 1988 ice year, an estimated 187 icebergs drifted south of 48°N latitude, compared to 318 icebergs drifting south of 48°N during 1987. The average number of icebergs drifting south of 48°N from 1900 to 1987 is 403 (Alfultis, 1987). With 187 icebergs drifting south of 48°N, 1988 was less than the average. The number of icebergs crossing 48°N during 1988 was less than the SLAR reconnaissance era average. It is important to note, however, that this SLAR era average is based on only five years of data.

IIP defines those ice years with less than 300 icebergs crossing 48°N as light or low ice years; those ice years with 300 to 600 icebergs crossing 48°N as average or intermediate; those ice years with 600 to 900 icebergs crossing 48°N as heavy or severe; and those ice years with more than 900 icebergs crossing 48°N as extreme. With 187 icebergs drifting south of 48°N, 1988 was deemed a light year.

On April 15, 1988, IIP paused to remember the 76th anniversary of the sinking of the RMS TITANIC. During an ice reconnaissance patrol, two memorial wreaths were placed near the site of the sinking to commemorate the nearly 1500 lives lost.

Six satellite-tracked ocean drifting buoys were deployed to provide operational data for IIP's iceberg drift model. These buoys were the same standard-size drifting buoys IIP has been deploying for thirteen years. Four of these buoys were later recovered by USCGC NORTHWIND for re-use. The drift data from these buoys are discussed in Appendix B.

In addition, four mini-drifting buoys were deployed in IIP's operations area as part of a joint IIP-Naval Oceanographic Research and Development Activity evaluation. One AES mini-drifting buoy was also deployed by IIP together with one IIP standard-size drifting buoy. These mini-drifting buoys are smaller with a lower cost per unit than the standard-size buoy. IIP is evaluating these mini-drifters for possible future operational use. The results of this evaluation are presented in Appendix B.

Prior to the start of the 1988 IIP season, IIP evaluated an Air-Deployed eXpendable BathyThermograph (AXBT) system. The AXBT measures temperature with depth, and transmits the data back to the aircraft. Based on the results of the evaluation, IIP put together an AXBT system and operationally deployed twelve AXBTs during the 1988 IIP season. The results of the evaluation and operational use of the AXBT system are presented in Appendix D.

The temperature data from the AXBTs were sent to the Canadian Meteorological and Oceanographic Center (METOC) in Halifax, Nova Scotia, Canada, the U.S. Naval Eastern Oceanography Center (NEOC) in Norfolk, Virginia, and FNOC. They use the AXBT data as inputs to their ocean temperature models. IIP directly benefits from its AXBT deployments by having improved ocean temperature data provided

Table 2. Total Icebergs South of 48° N - The four periods shown are pre-International Ice Patrol (1900-12), ship reconnaissance (1913-45), aircraft visual reconnaissance (1946-82), and SLAR reconnaissance (1983-87).

	Total 1900-12	Total 1913-45	Total 1946-82	Total 1983-87	1988
OCT	27	80	2	3	0
NOV	13	93	4	11	0
DEC	38	42	11	14	0
JAN	33	87	65	13	0
FEB	79	372	273	239	0
MAR	898	1204	1172	442	8
APR	1537	3308	3131	1636	95
MAY	1611	5472	2993	1242	33
JUN	1004	2514	1865	793	20
JUL	423	773	489	567	19
AUG	160	229	100	138	10
SEP	58	188	10	41	2
Total	5,881	14,362	10,115	5,139	187

Table 3. Average Number of Icebergs South of 48° N - The four periods shown are pre-International Ice Patrol (1900-12), ship reconnaissance (1913-45), aircraft visual reconnaissance (1946-82), and SLAR reconnaissance (1983-87).

	Avg 1900-12	Avg 1913-45	Avg 1946-82	Avg 1983-87	1988
OCT	2	2	0	1	0
NOV	1	3	0	2	0
DEC	3	1	0	3	0
JAN	2	3	2	3	0
FEB	6	11	7	48	0
MAR	69	36	32	88	8
APR	118	100	85	327	95
MAY	124	166	81	248	33
JUN	77	76	50	159	20
JUL	32	23	13	113	19
AUG	12	7	3	28	10
SEP	4	6	0	8	2
Era Average	452	435	273	1,028	187

to its iceberg deterioration model. To further enhance the quality of environmental data used in its iceberg models, IIP also provided weekly drifting buoy drift and sea surface temperature (SST) histories, and SLAR ocean feature analyses to METOC and NEOC. They used this information in their water mass and SST analyses.

No U. S. Coast Guard cutters were deployed to act as surface patrol vessels this year. USCGC NORTHWIND was deployed from June 3 to 27 to act as a surface truth vessel for an international SLAR evaluation experiment, SLAREX '88. Two U.S. Coast Guard and two Canadian AES SLAR-equipped aircraft participated in SLAREX '88. The primary goal of the experiment was to evaluate the ability of the AN/APS-131 SLAR on the HU-25B aircraft to detect icebergs. The results of SLAREX '88 are presented in Appendix E.

The 1988 season marked the 25th full year of IIP service for the HC-130 'Hercules' aircraft. A 'Hercules' flew one ice reconnaissance patrol in 1963. The HC-130 assumed the Ice Patrol aerial reconnaissance responsibilities for the 1964 season until the present.

Iceberg Reconnaissance and Communications

During the 1988 Ice Patrol year (from October 1, 1987, through September 30, 1988), 86 aircraft sorties were flown in support of the International Ice Patrol. These included pre-season flights, ice observation flights during the season, post season flights, logistics flights, and SLAR research flights. Pre-season flights determined iceberg concentrations north of 48°N. These iceberg concentrations were needed to estimate the time when icebergs would threaten the North Atlantic shipping lanes in the vicinity of the Grand Banks of Newfoundland. During the active season, ice observation flights located the southwestern, southern, and southeastern limits of icebergs. Logistics flights were necessary to support the patrol aircraft due to aircraft maintenance problems. Post season flights were made to check on the iceberg distribution, to retrieve parts and equipment from Gander, and to close out all business transactions from the season. The SLAR research flights were in support of SLAREX '88.

Aerial ice reconnaissance was conducted with SLAR-equipped HC-130H aircraft, and, for the first time, with a SLAR-equipped HU-25B aircraft. The U.S. Coast Guard HC-130H aircraft deployed from Coast Air Station Elizabeth City, North Carolina. The U.S. Coast Guard HU-25B aircraft deployed from Coast Guard Air Station Cape Cod, Massachusetts. The HC-130H and HU-25B aircraft both participated in SLAREX '88. HC-130 aircraft were used on logistics flights. Table 4 shows aircraft use during the 1988 ice year.

Aircraft Deployment	**Sorties**	**Flight Hours**
Pre-season	16	92.7
Regular Season	50	272.0
Post Season	3	16.9
SLAR Research	17	53.2
Total	86	434.8

Iceberg Reconnaissance Sorties by Month

Month	**Sorties**	**Flight Hours**
Feb	3	21.0
Mar	4	28.1
Apr	7	43.7
May	8	51.3
Jun	11	68.8
Jul	5	32.1
Aug	2	12.4
Total	40	257.4

Table 4. Aircraft use during the 1988 IIP Year (October 1, 1987 - September 30, 1988)

Table 5. Iceberg and Sea Surface Temperature Reports.

Number of ships furnishing Sea Surface Temperature (SST) reports	39
Number of SST reports received	200
Number of ships furnishing ice reports	255
Number of ice reports received	711
First Ice Bulletin	130000Z APR 88
Last Ice Bulletin	021200Z AUG 88
Number of facsimile charts transmitted	110

The IIP prepares the ice bulletin warning mariners of the southwestern, southern, and southeastern limits of icebergs twice a day for broadcast at 0000Z and 1200Z. The IIP also prepares a facsimile chart graphically depicting these limits for broadcast at 1600Z. U.S. Coast Guard Communications Station Boston, Massachusetts, NMF/NIK, was the primary radio station used for the dissemination of the daily ice bulletins and facsimile charts. Other transmitting stations for the 0000Z and 1200Z ice bulletins were Canadian Coast Guard Radio Station St. John's/VON, Canadian Forces Meteorological and Oceanographic Center (METOC) Halifax, Nova Scotia/CFH, and U.S. Navy LCMP Broadcast Stations Norfolk/NAM; Thurso, Scotland; and Keflavik, Iceland.

Canadian Forces METOC, Halifax/CFH, as well as AM Radio Station Bracknell/GFE, United Kingdom, are radiofacsimile broadcasting stations which used Ice Patrol limits in their broadcasts. Canadian Coast Guard Radio Station St. John's/ VON and U.S. Coast Guard Communications Station Boston/NIK provided special broadcasts.

The International Ice Patrol requested that all ships transiting the area of the Grand Banks report ice sightings, weather, and sea surface temperatures via the above communications/radio stations. Response to this request is shown in Table 5. Appendix A lists all contributors. Commander, International Ice Patrol extends a sincere thank you to all stations and ships which contributed.

For the first time, IIP was directly linked in 1988 to Canadian Coast Guard Radio St John's/ VON, Ice Operations St. John's, Ice Centre Ottawa, and the offshore oil industry via an electronic mail system with telex as a backup. Canadian Radio Station St John's/VON passed all iceberg sighting reports it received to IIP via Ice Operations St. John's. Ice Operations St John's converted the iceberg sighting report to the computer compatible joint AES/IIP iceberg code. This ensured better accountability and more timely receipt of the iceberg sighting reports. IIP and AES reconnaissance detachments have been using the computerized code since the 1986 season. The offshore oil industry conducts aerial ice reconnaissance in the vicinity of oil exploration on the Grand Banks. Their sighting reports are transmitted directly to Groton.

Environmental Conditions 1988 Season

The wind direction along the Labrador and Newfoundland coasts can affect the iceberg severity of each ice year. The mean wind flow can influence iceberg drift. Dependent upon wind intensity and duration, icebergs can be accelerated along or driven out of the main flow of the Labrador Current. Departure from the Labrador Current normally slows their southerly drift, and in many cases speeds up their rate of deterioration.

The wind direction and air temperature affect the iceberg severity of each ice year in an indirect way by influencing the extent of sea ice. Sea ice protects the icebergs from wave action, the major agent of iceberg deterioration. If the air temperature and wind direction are favorable for the sea ice to extend to the south and over the Grand Banks of Newfoundland, the icebergs will be protected longer as they drift south. When the sea ice retreats in the spring, large numbers of icebergs are left behind on the Grand Banks. Also, if the time of sea ice retreat is delayed by below normal air temperatures, the icebergs will be protected longer, and a longer than normal ice season can be expected. The opposite is true if the southerly sea ice extent is less than average, or if above normal air temperatures cause an early retreat of sea ice from the Grand Banks.

The following discussion summarizes the environmental conditions along the Labrador and Newfoundland coasts for the 1988 ice year.

January: The monthly mean pressure of the Icelandic Low was 10 mb lower in January than normal (Figure 2). This resulted in stronger, slightly more westerly winds along the Labrador Coast (AES, 1988), and strong westerly winds over the waters east of Newfoundland in January.

February: A double-centered Icelandic Low formed this month on either side of Iceland (Figure 3). This is not unusual, but when a double-centered Icelandic Low forms, the two centers are usually near Denmark Strait and off Norway (Mariners Weather Log, 1988b). The two lows were also deeper than normal. This led to a -8 mb anomaly centered in Davis Strait (Mariners Weather Log, 1988b), and a stronger than normal northwesterly flow along the Labrador Coast. A westerly flow dominated the waters east of Newfoundland. The flow was more offshore than normal in both of these areas (AES, 1988).

March: The Azores-Bermuda High dominated the western North Atlantic in March, and its monthly mean pressure was 6 mb higher than normal (Figure 4). This displaced the Icelandic Low to the west, and caused a -4 mb anomaly in the Labrador Sea (Mariners Weather Log, 1988b). The winds in March were near normal, however, with northwesterly winds along the Labrador Coast and westerly winds east of Newfoundland (AES, 1988).

April: In April, the Azores-Bermuda High usually begins to build in strength while the Icelandic Low begins to decrease in intensity (Mariners Weather Log, 1988c). In 1988, the Azores-Bermuda High was near its normal position and intensity (Figure 5). However, with a monthly mean pressure 4 mb lower than normal, the Icelandic Low was more intense and farther west than normal. This resulted in strong, northeasterly winds along Labrador and eastern Newfoundland rather than the normal lighter, more northerly winds.

May: In May, the Azores-Bermuda High began to dominate the North Atlantic (Figure 6). It was slightly stronger than normal, but storm activity to the north kept it from its normal expansion (Mariners Weather Log, 1988c). The resulting flow pattern along Labrador and eastern Newfoundland was light northeasterly winds rather than the normal light southwesterlies.

June: With a monthly mean pressure 4 mb higher than normal, the Azores-Bermuda High was again stronger than normal in June (Figure 7). However, over Newfoundland, the Icelandic low was also 5 mb lower than normal (Mariners Weather Log, 1988c). These features resulted in tight gradients from Nova Scotia to Denmark. The resulting flow pattern east of Newfoundland was stronger than normal southeasterly winds.

July: The Azores-Bermuda High continued to be slightly stronger than normal in July, but the Icelandic Low continued to persist unseasonably through July (Figure 8). The winds along Labrador and eastern Newfoundland, however, were near normal southwesterlies.

August: The Azores-Bermuda High was nearly normal in August, and the Icelandic Low was again more intense than normal (Figure 9). This resulted in tighter than normal pressure gradients across the North Atlantic (Mariners Weather Log, 1989). The resulting flow along Labrador and eastern Newfoundland would be stronger than normal westerly winds.

September: Both the Azores-Bermuda High and Icelandic Low were stronger than normal in September (Figure 10). The monthly mean pressure of the Azores-Bermuda High was 3 mb higher than normal. The Icelandic Low once again had a double center, resulting in -4 to -5 mb anomalies over Labrador (Mariners Weather Log, 1989). The resulting flow pattern would be a stronger than normal westerly winds for Newfoundland, and very light northerly winds for Labrador.

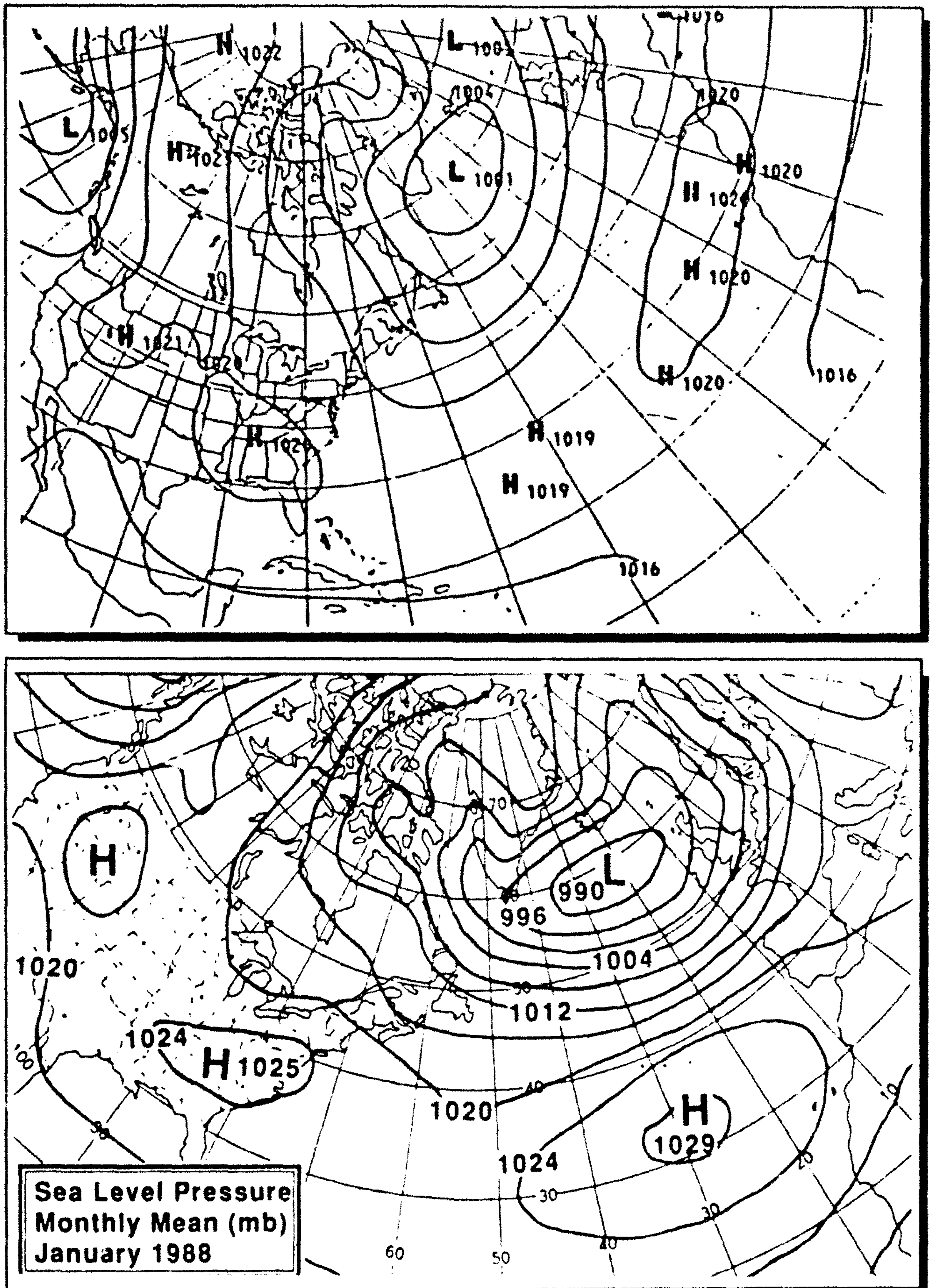


Figure 2. Comparison of January 1988 monthly mean surface pressure in mb (bottom, from Mariner's Weather Log, 1988b) with January historical average, 1948-1970 (top).

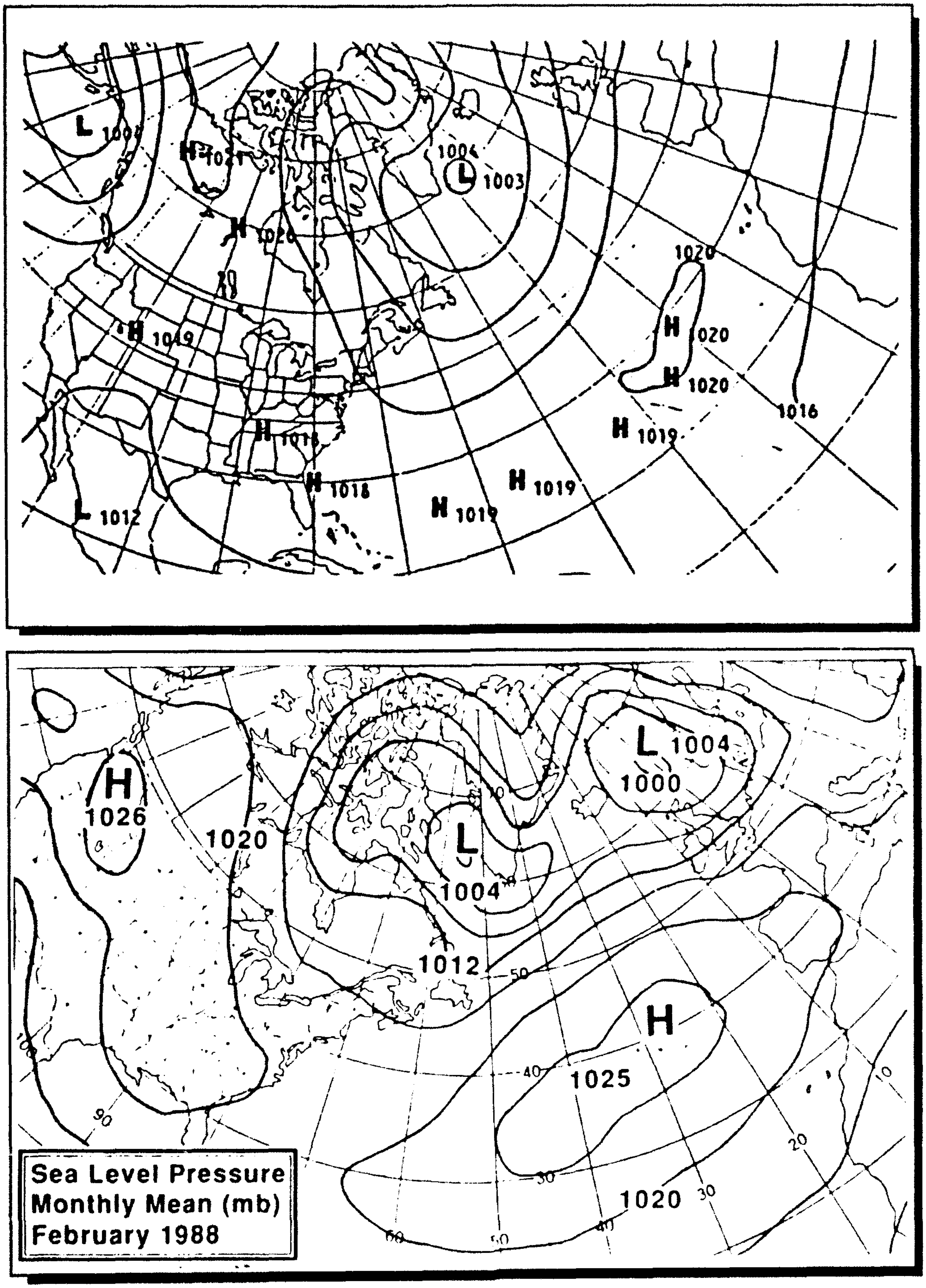


Figure 3. February 1988 (from Mariner's Weather Log, 1988b) .

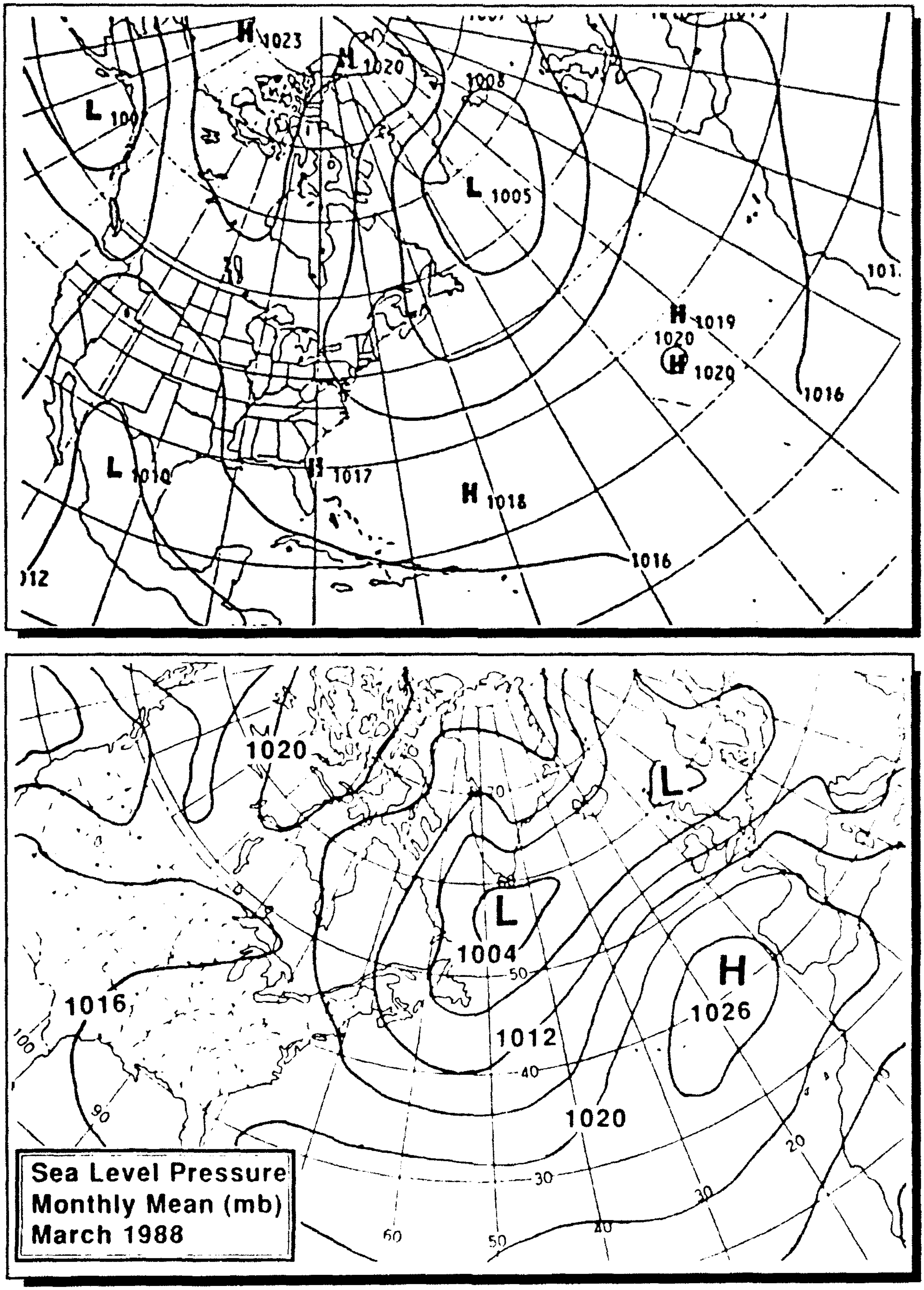
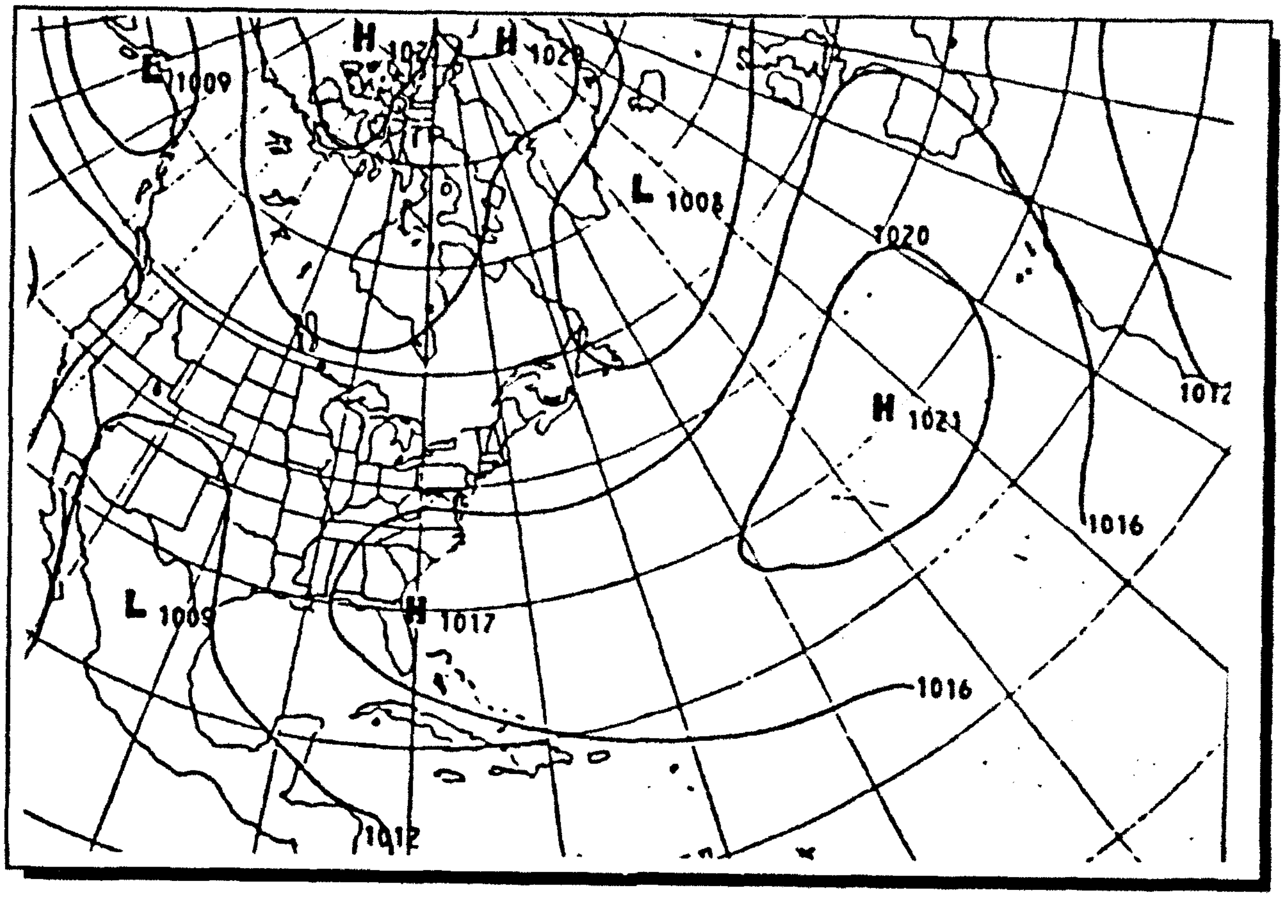


Figure 4. March 1988 (from Mariner's Weather Log, 1988b) .



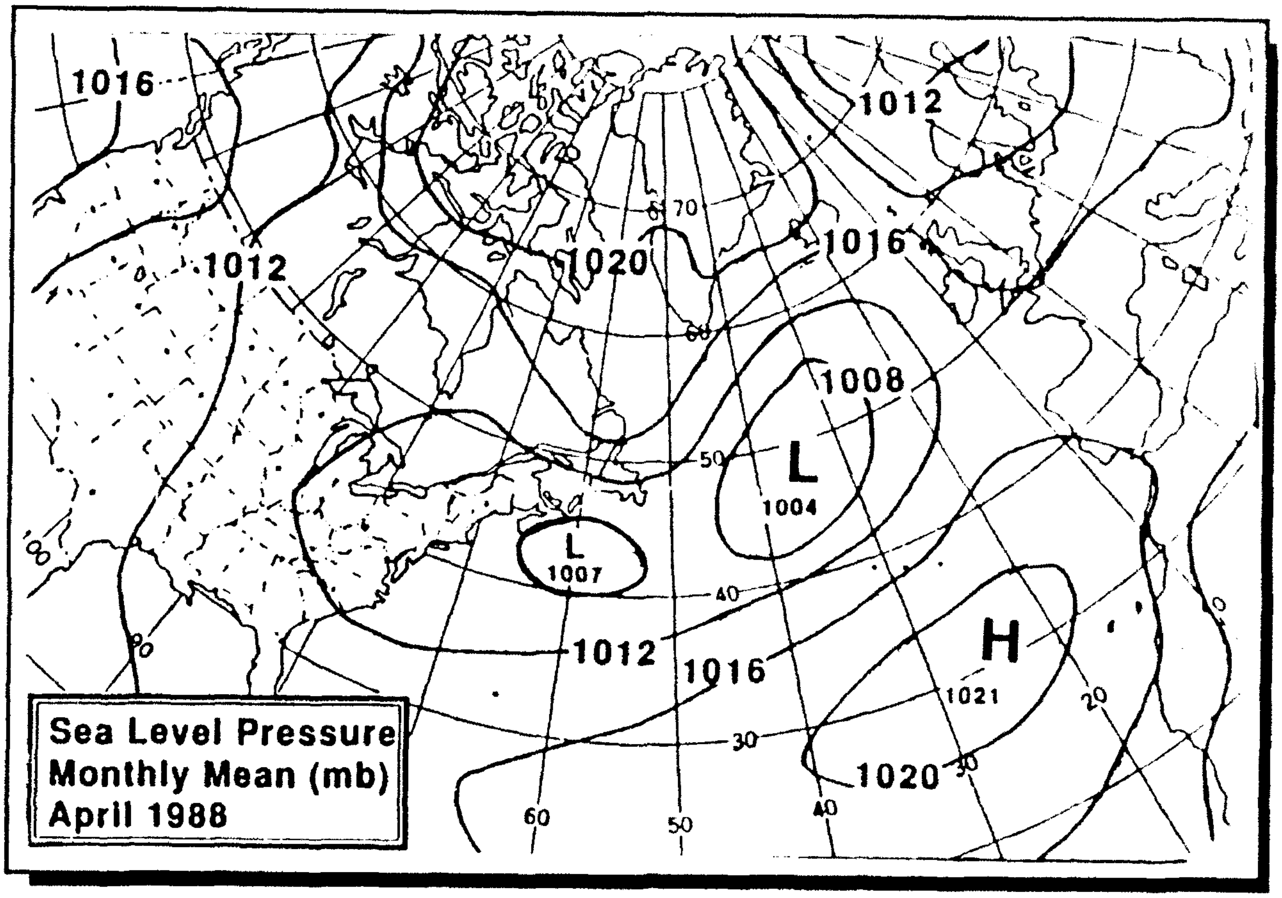


Figure 5. April 1988 (from Mariner's Weather Log, 1988c).

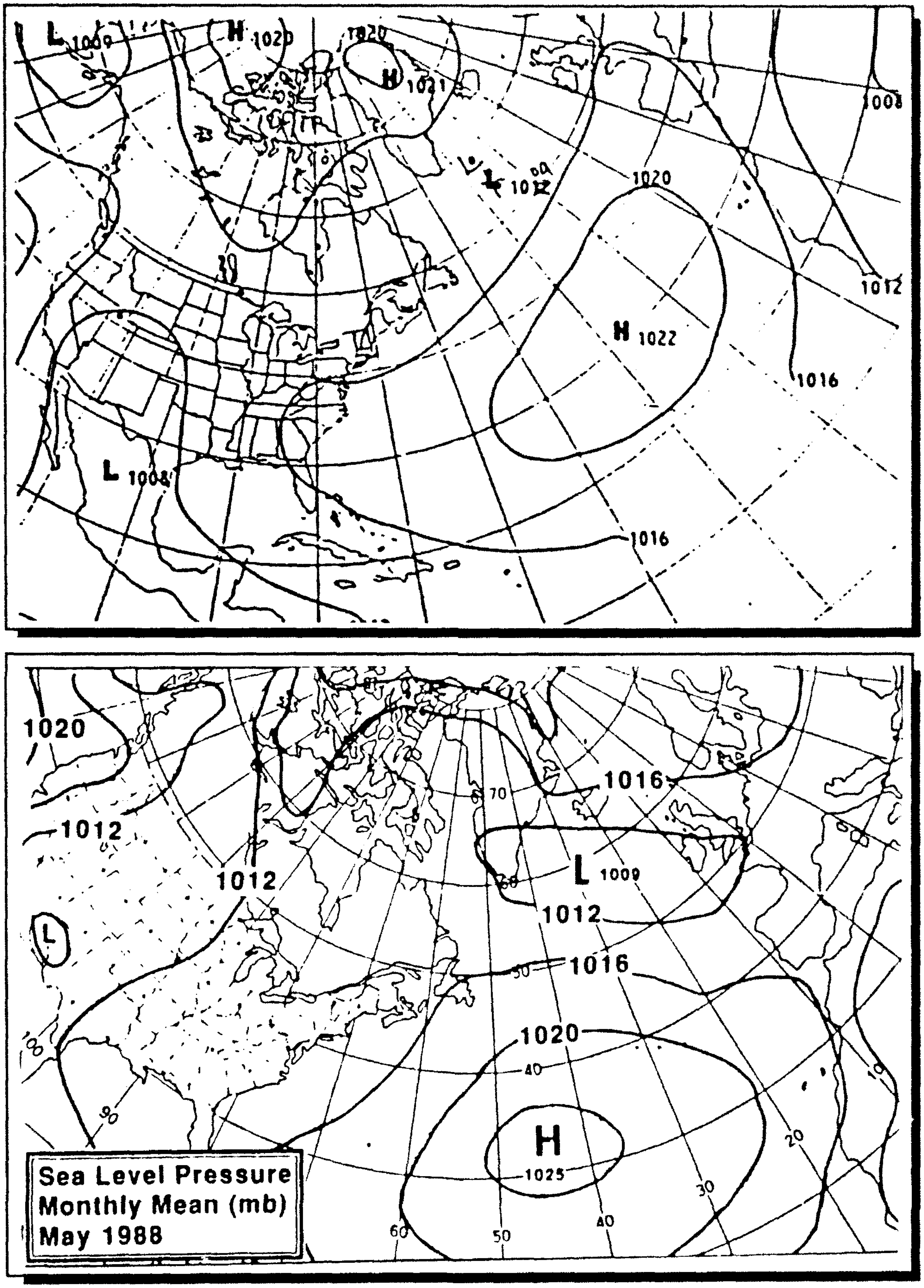


Figure 6. May 1988 (from Mariner's Weather Log, 1988c).

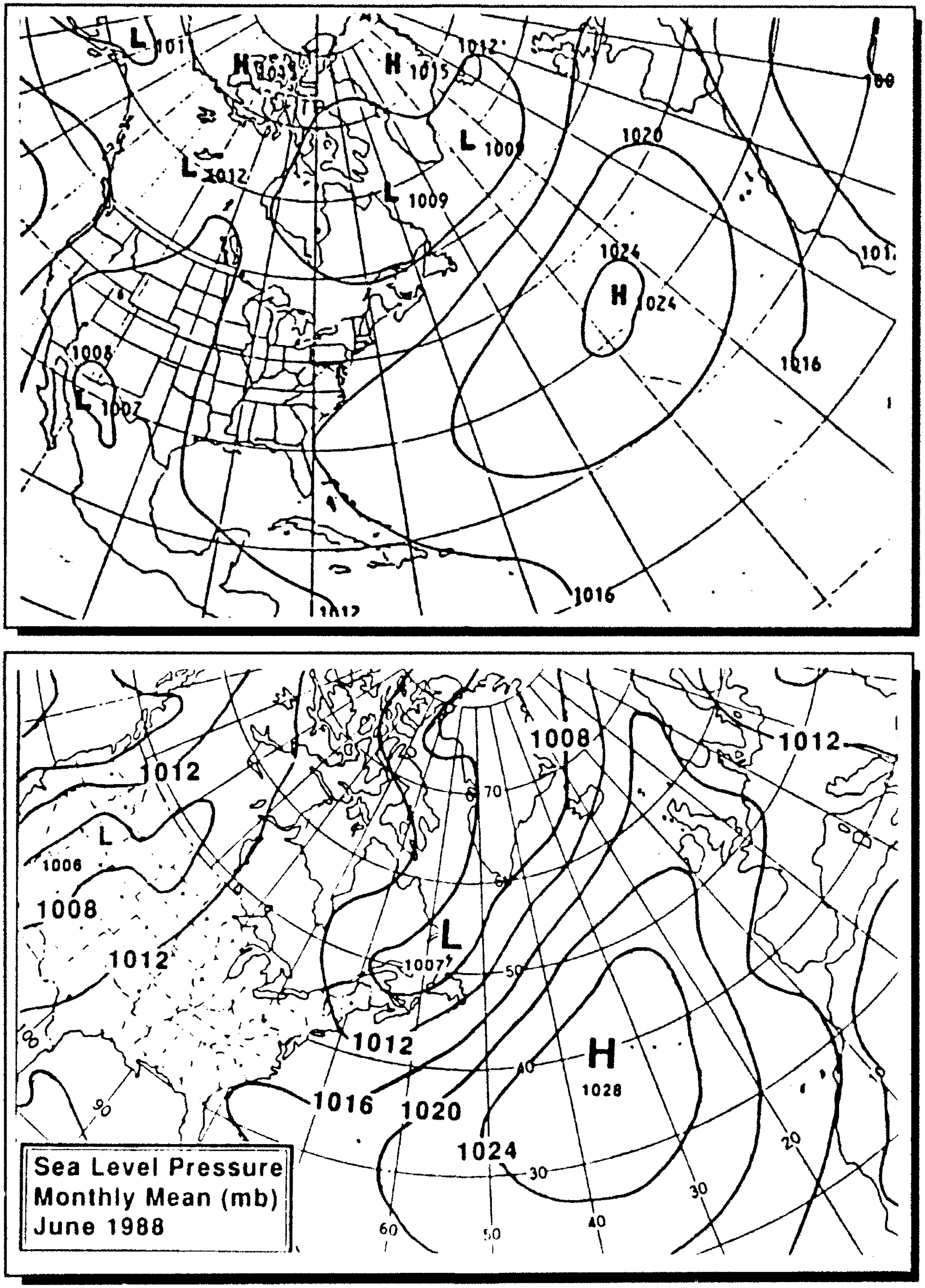


Figure 7. June 1988 (from Mariner's Weather Log, 1988c).

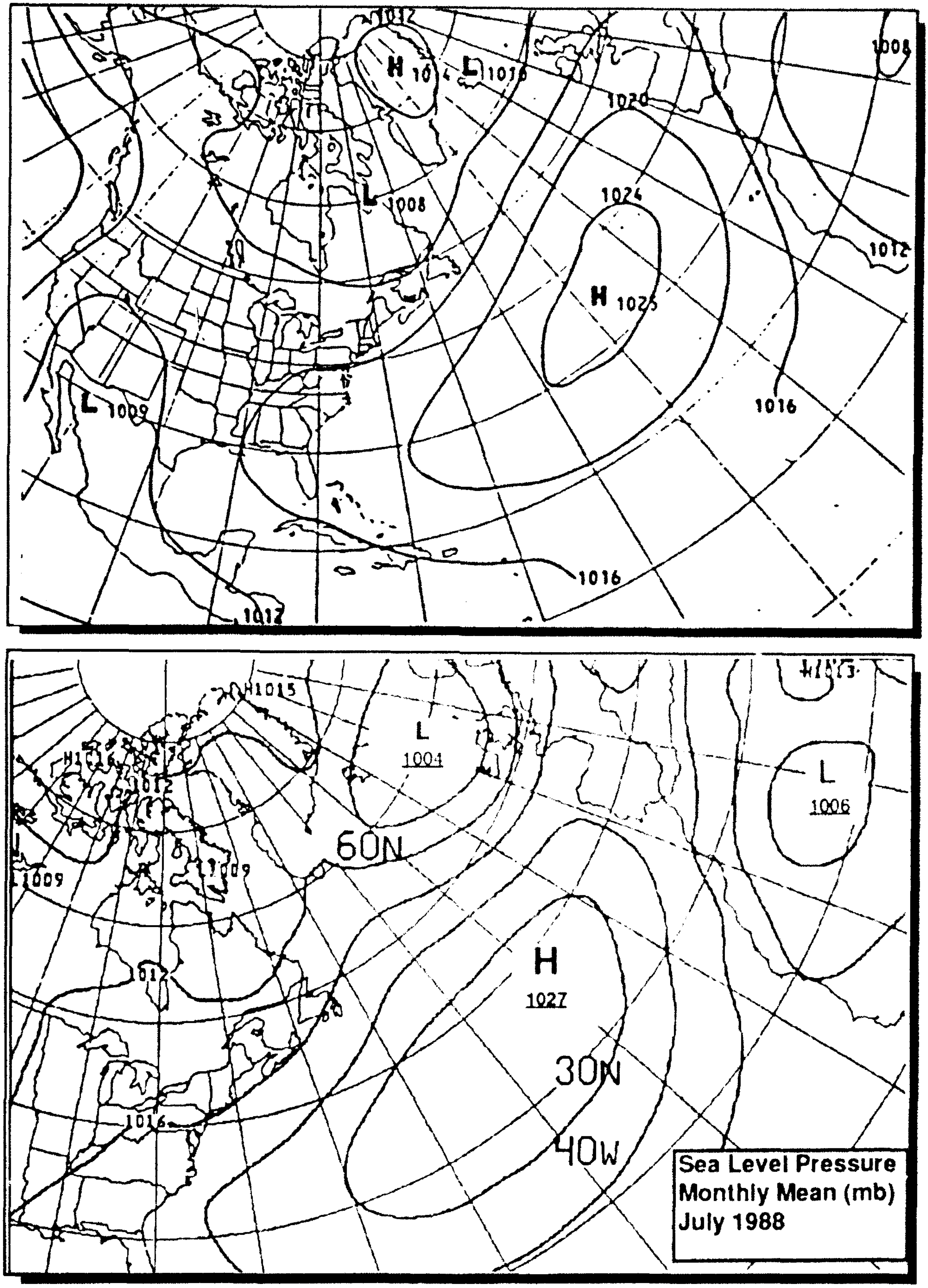


Figure 8. July 1988 (from Mariner's Weather Log, 1989) .

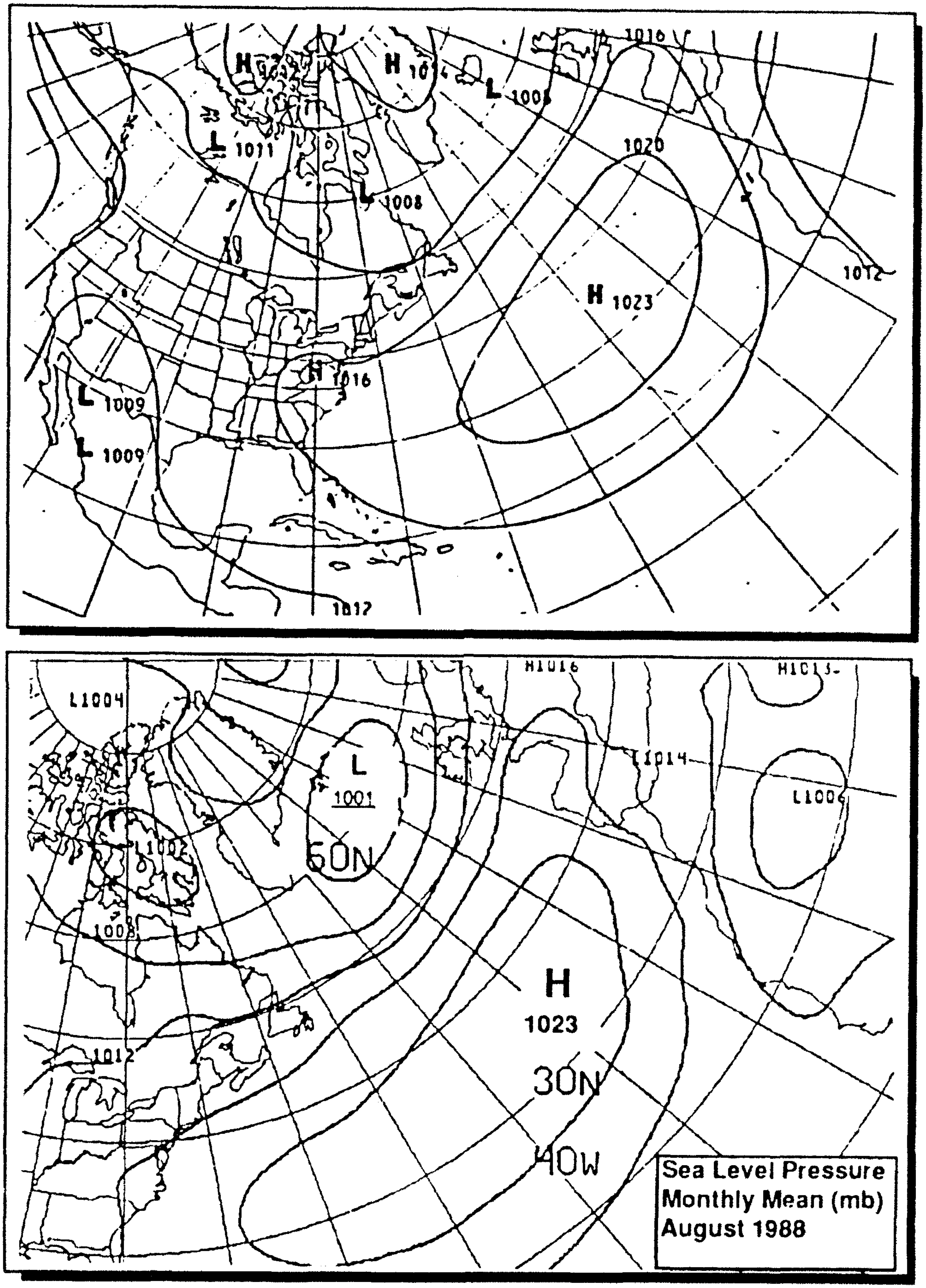
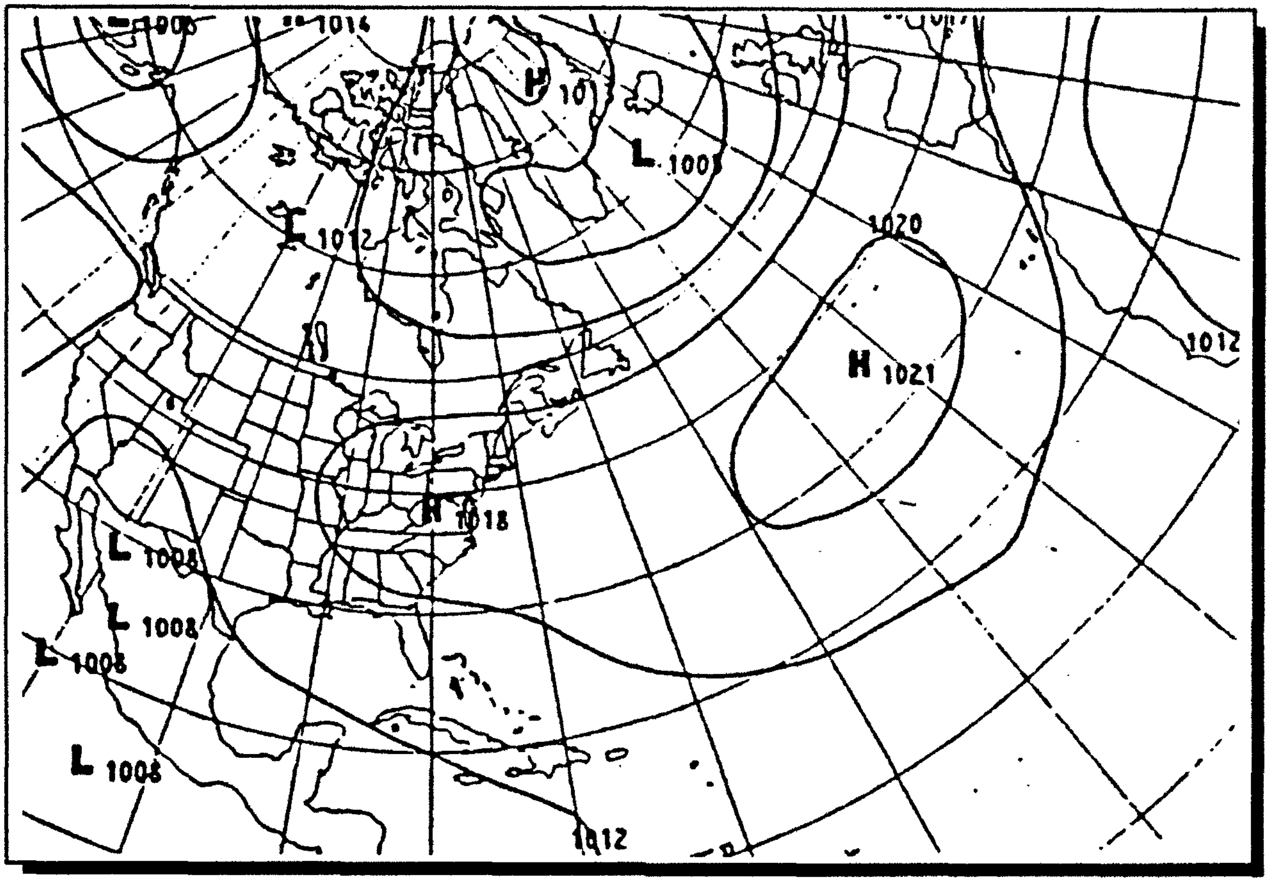


Figure 9. August 1988 (from Mariner's Weather Log, 1989) .



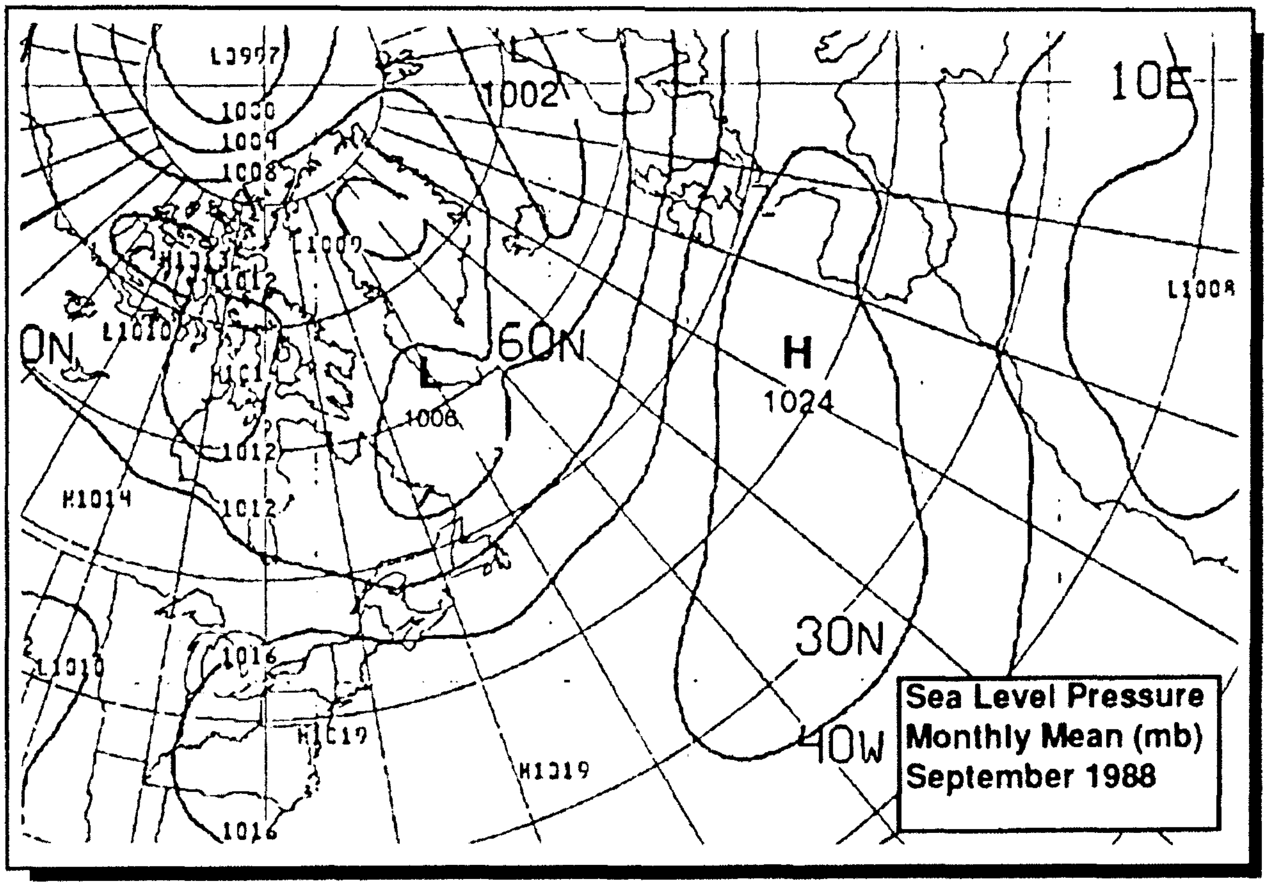


Figure 10. September 1988 (from Mariner's Weather Log, 1989)

Ice Conditions 1988 Season

The following discussion summarizes the sea ice and iceberg conditions along the Labrador and Newfoundland coasts and on the Grand Banks of Newfoundland for the 1988 ice year. The sea ice information used in this discussion came from the Thirty Day Ice Forecast for Northern Canadian Waters published monthly by the Atmospheric Environment Service (AES) of Canada and the Southern Ice Limit published twice-monthly by the U.S. Navy-NOAA Joint Ice Center. Information on the mean sea ice extent was obtained from Naval Oceanography Command, 1986.

October 1987: No sea ice was seen south of 65°N in October (Figure 11), which is normally the case (Naval Oceanographic Command, 1986). There were six icebergs reported south of 52°N in October, but none of these were south of 48° N.

November 1987: In mid-November, sea ice began to form in Davis Strait and Frobisher Bay (Figure 12). The mean extent of sea ice in November was confined to the southern tip of Baffin Island with the maximum sea ice extent covering Hudson Strait, and Ungava Bay (Naval Oceanographic Command, 1986). The ice edge in November 1987 did not extend as far south as the mean. There was only one iceberg reported south of 52° N in November, and none reported south of 48° N.

December 1987: The sea ice edge extended to the northern tip of Labrador by mid-December (Figure 13). The mean extent of sea ice along the Labrador coast in December is usually as far south as Lake Melville. Mild temperatures in Labrador and Newfoundland during the first half of December (AES, 1988), prevented the sea ice from extending as far south as the mean. There were no icebergs reported south of 52° N in December.

January 1988: Cold temperatures during the last half of December and into January (AES, 1988) enhanced sea ice growth. As a result, by mid-January, the sea ice conditions were nearly normal for this time of year (Figure 14). There were no icebergs reported south of 52° N in January.

February 1988: Below normal temperatures continued into February. Labrador and northern Newfoundland reported temperatures about 5° to 7° C below normal while central and southern Newfoundland were about 2° to 4° C below normal (AES, 1988). In addition, the average winds had more of an offshore component than normal. As a result, the sea ice was thicker than normal (AES, 1988), and extended farther east than normal (Figure 15). The ice edge extended south along Newfoundland to the Avalon Peninsula. The ice conditions in mid-February were similar to that normally expected for the end of February, so the ice conditions had developed two weeks earlier than normal (AES, 1988). There were 67 icebergs observed south of 52°N in February; but none were reported south of 48°N.

March 1988: The sea ice edge was farther north in mid-March than it was in mid-February (Figure 16). Temperatures for the last two weeks of February were 1° to 2° C above normal over the waters east of Newfoundland (AES, 1988). As a result, the sea ice edge did not extend as far south as it normally does. The winds continued to have an offshore component (AES, 1988), keeping the eastern sea ice edge near normal. There were 35 icebergs reported south of 52° N, and 8 reported south of 48° N.

April 1988: The sea ice edge continued to retreat northward in April, but at a rate faster than normal (Figure 17). By mid-April, the sea ice edge was confined to very close to the Newfoundland coast north of Cape Freels and along the Labrador coast north of the Strait of Belle Isle. Northeasterly winds pushed the ice edge to the west, and above normal temperatures over Labrador (AES, 1988) increased sea ice deterioration. The 1988 International Ice Patrol Season opened on April 13, 1988. Figure 23 depicts the initial iceberg distribution. The icebergs were widely scattered over the Grand Banks of Newfoundland. None of the icebergs south of 52° N at the start of the season appear to be in the Labrador Current.

(Figure 33 inside the back cover depicts the mean position of the Labrador Current.) Figure 24 shows the iceberg distribution a few days into the season. Most of the icebergs reported were on the Grand Banks with some now coming down the Avalon Channel east of Newfoundland. A few icebergs appeared to be drifting with the Labrador Current along the eastern edge of the Grand Banks. By the end of April (Figure 25), the icebergs were widely scattered, with most still being reported on the Grand Banks. There were 114 icebergs on plot the end of April. There were 151 icebergs reported south of 52° N, and 95 reported south of 48° N in April.

May 1988: Some sea ice continued to linger in Notre Dame Bay, but the main pack of sea ice continued to retreat northward along the Labrador coast in May (Figure 18). The sea ice edge was again farther north than the mean. The icebergs were not as scattered in mid-May as they were in the end of April (Figure 26). Most of the icebergs were either along the Newfoundland coast or on the Grand Banks. By the end of May, large numbers of icebergs began to enter IIP's operations area from the north (Figure 27). Few of these icebergs crossed 48° N by the end of May. There were 177 icebergs on plot the end of May. There were 223 new icebergs south of 52° N, but only 33 of these were south of 48° N, in May.

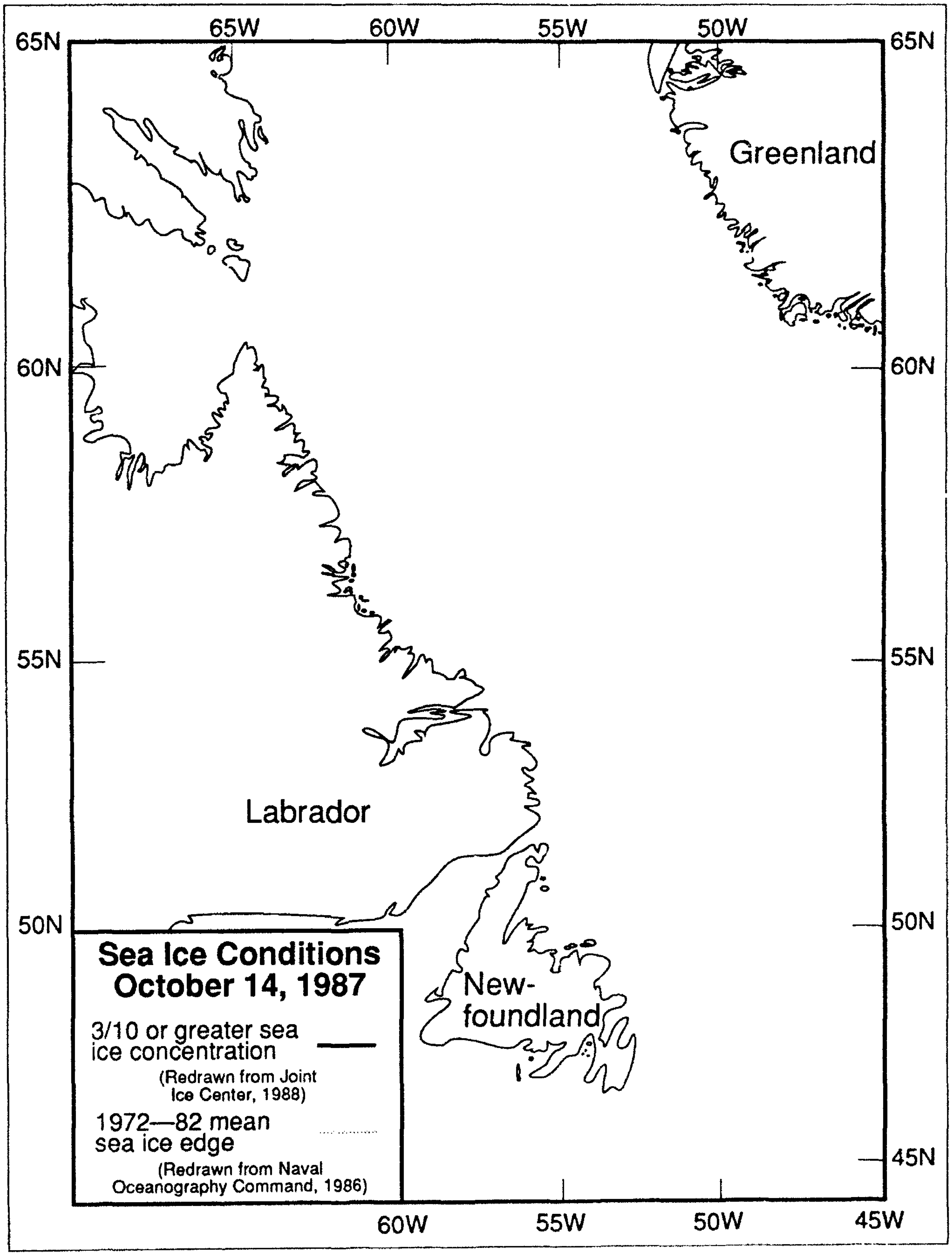
June 1988: The sea ice edge continued to move northward in June (Figure 19). The southerly extent of sea ice was near normal for June, but the sea ice edge did not extend as far east as normal. In mid-June, there were still large numbers of icebergs east of Newfoundland (Figure 28), but not many of these icebergs were making their way south through Flemish Pass. Most of the icebergs were moving south along the Newfoundland coast through the Avalon Channel. On June 24, the southern most iceberg of the 1988 IIP season was sighted in position 42°13' N, 46°59' W. By the end of June, most of the icebergs were distributed to the north and east of the Grand Banks and Flemish Cap., with very few to the south (Figure 29). There were 356 icebergs on plot the end of June. There were 300 new icebergs south of 52° N in May, and only 20 of these were south of 48° N.

July 1988: By mid-July, the sea ice had retreated to a tongue off the northern tip of Labrador (Figure 20). This tongue of sea ice extended farther to the south than normal. On July 7, the easternmost iceberg of the 1988 IIP season was reported in position 51°19' N, 42°55' W. By mid-July, the IIP estimated limit of all known ice was also moving northward (Figure 30). The icebergs were predominantly distributed north and east of the Grand Banks and Flemish Cap. The iceberg distribution remained essentially the same to the end of July (Figure 31). There were 80 icebergs on plot the end of July. There were 327 new icebergs south of 52° N in July. Only 19 of these were south of 48° N.

August 1988: Only a very little sea ice off of Baffin Island remained south of 65° N in August (Figure 21). Normally, there is no sea ice south of 65° N in August. The 1988 IIP season closed August 2, 1988. Figure 32 depicts the iceberg distribution at the end of the IIP season. There were 225 icebergs south of 52° N in August, and only 10 of these were south of 48° N.

September 1988: There was no sea ice south of 65° N in September, which is normally the case (Figure 22). There were 15 new icebergs south of 52° N in September, and two of these were south of 48° N.

Figure 11.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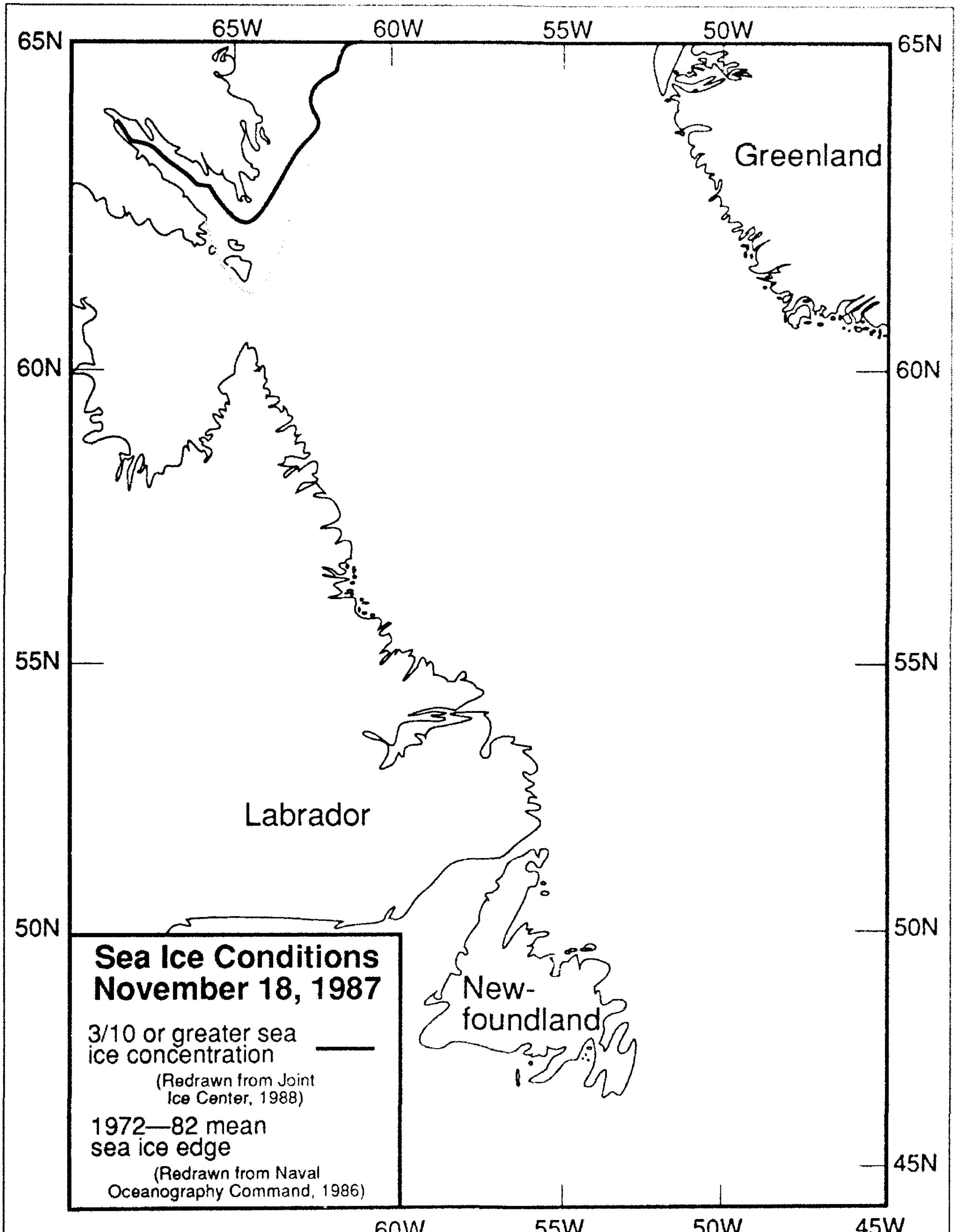
45W
Greenland
Labrador
New-
foundland
Sea Ice Conditions
October 14, 1987
3/10 or greater sea
ice concentration
(Redrawn from Joint
Ice Center, 1988)
1972—82 mean
sea ice edge
(Redrawn from Naval
Oceanography Command, 1986)

Figure 12.



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Greenland
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Labrador
50N
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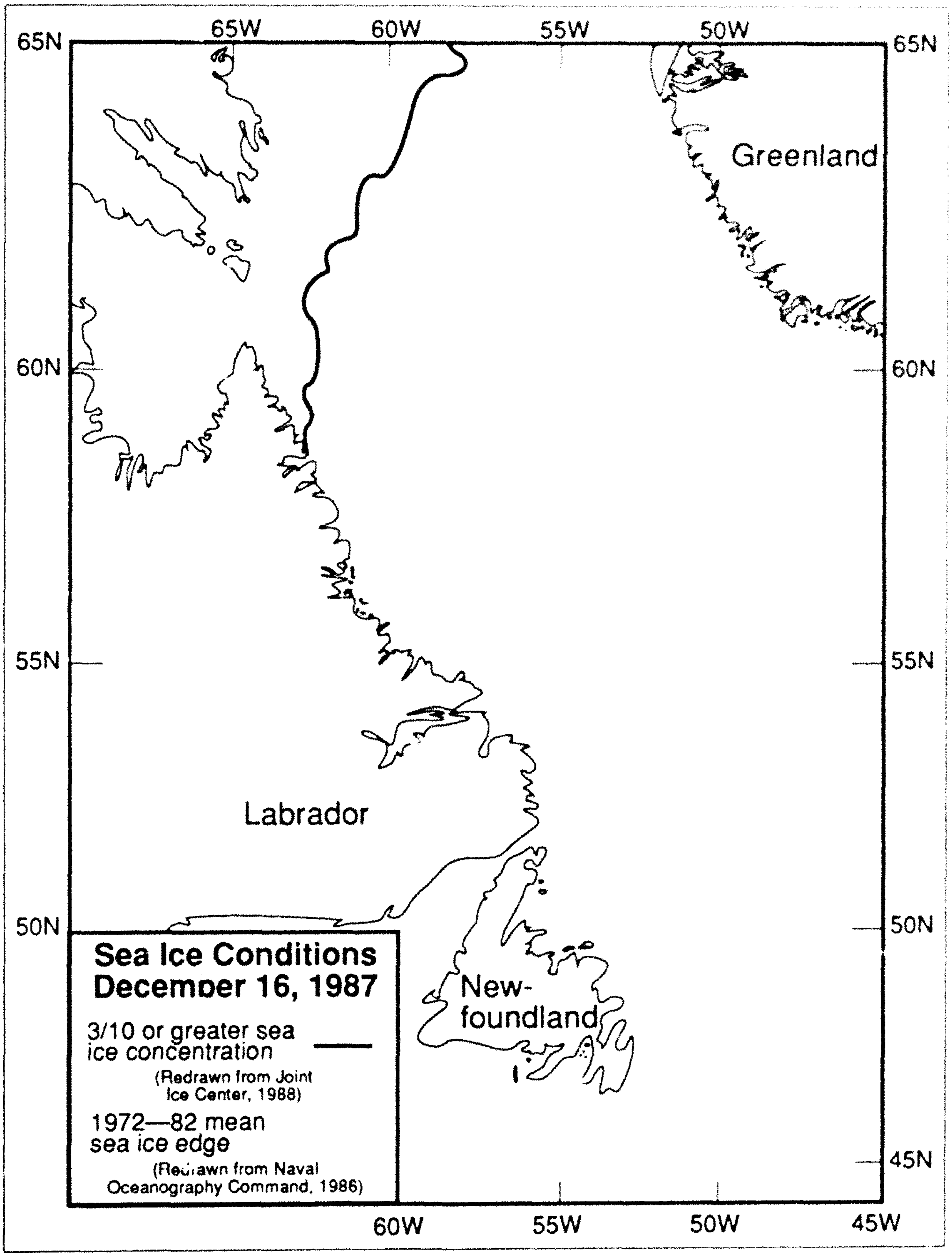
Sea Ice Conditions
November 18, 1987
3/10 or greater sea ice concentration
(Redrawn from Joint Ice Center, 1988)
1972—82 mean sea ice edge
(Redrawn from Naval Oceanography Command, 1986)
New-
foundland
45N
60W
55W
50W
45W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Greenland
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Labrador
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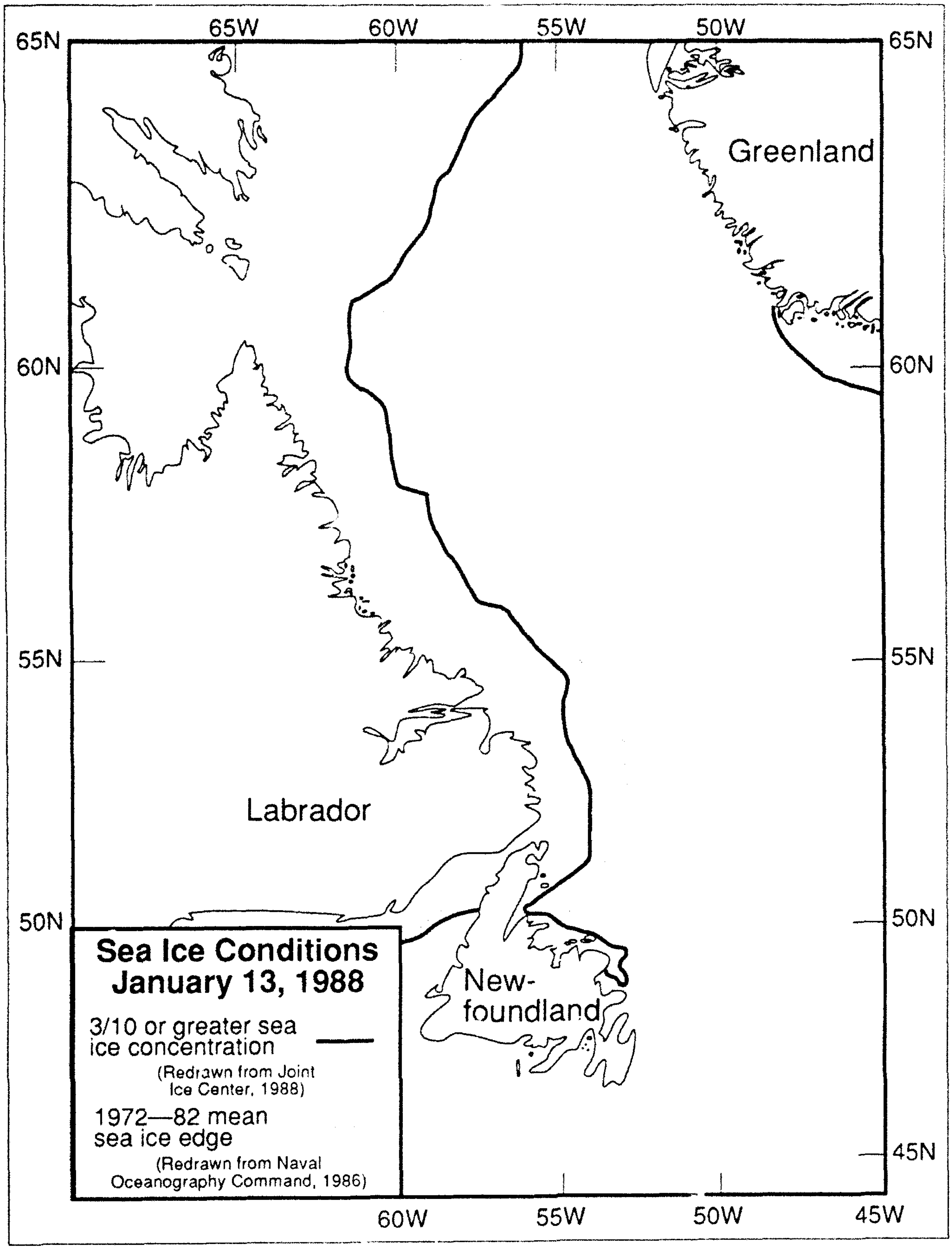
Sea Ice Conditions
December 16, 1987
3/10 or greater sea ice concentration
(Redrawn from Joint Ice Center, 1988)
1972—82 mean sea ice edge
(Redrawn from Naval Oceanography Command, 1986)
New-foundland
45N
60W
55W
50W
45W

Figure 14.



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45N
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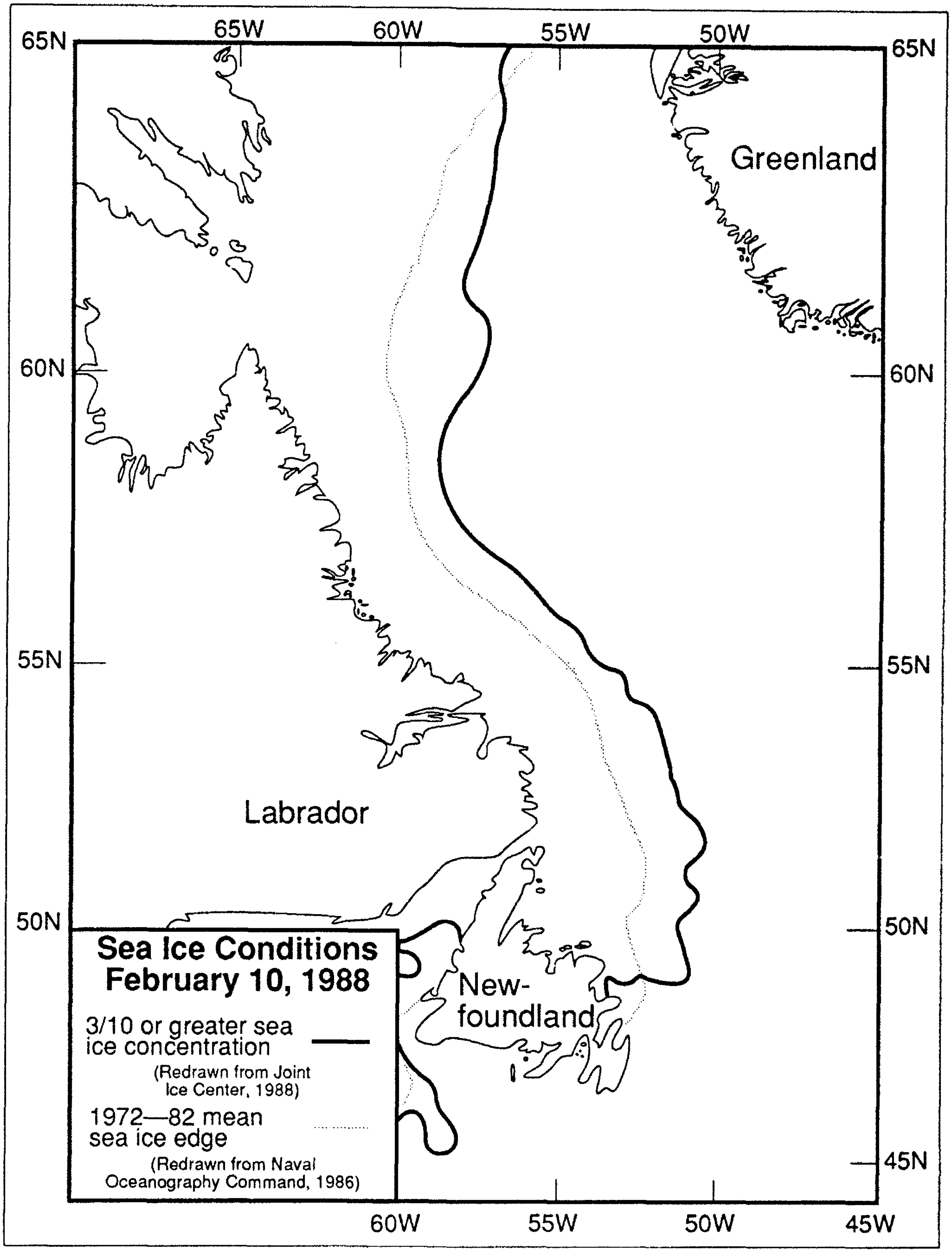
Greenland
Labrador
New-
foundland
Sea Ice Conditions
January 13, 1988
3/10 or greater sea
ice concentration
(Redrawn from Joint
Ice Center, 1988)
1972—82 mean
sea ice edge
(Redrawn from Naval
Oceanography Command, 1986)

Figure 15.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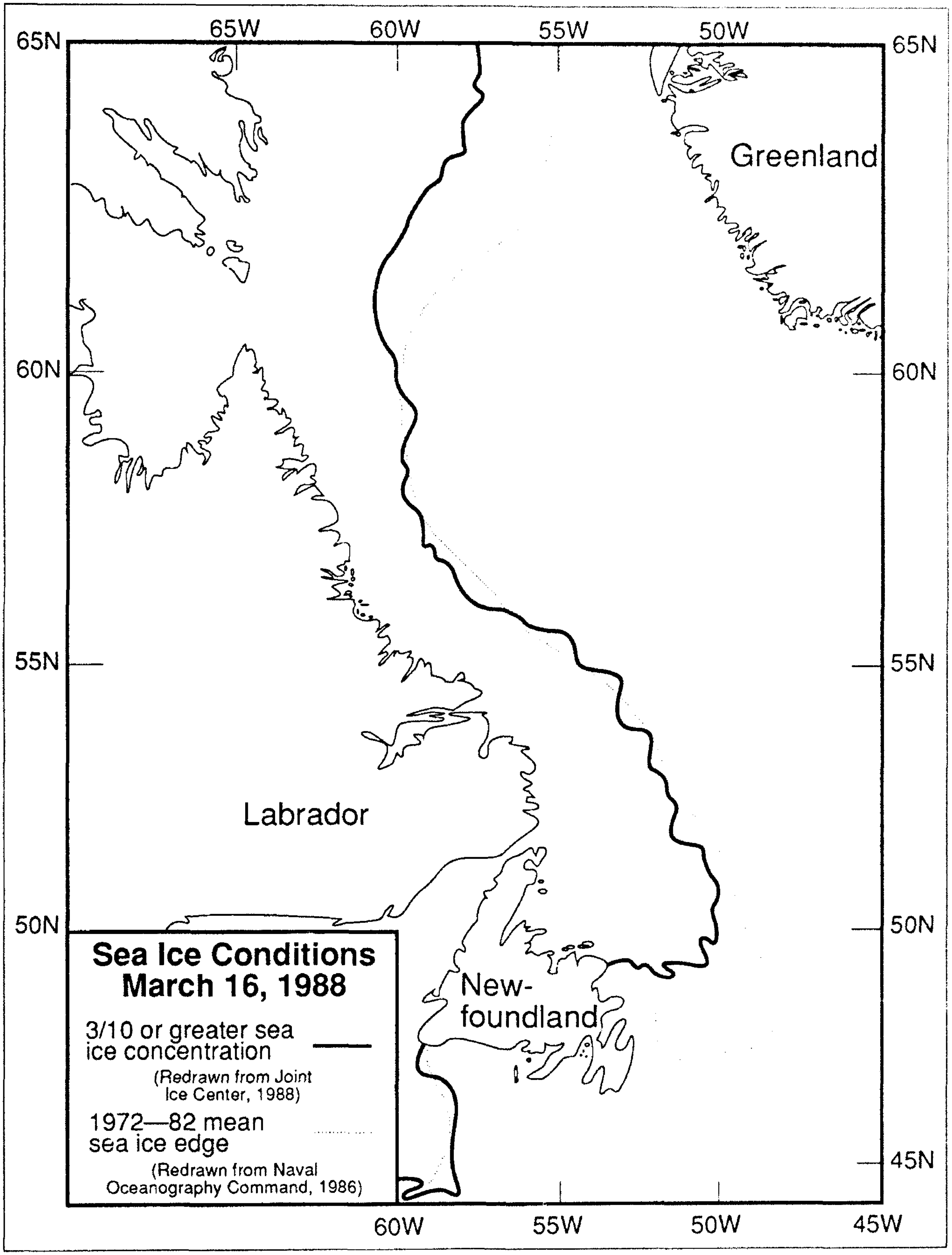
Greenland
Labrador
New-
foundland
Sea Ice Conditions
February 10, 1988
3/10 or greater sea
ice concentration
(Redrawn from Joint
Ice Center, 1988)
1972—82 mean
sea ice edge
(Redrawn from Naval
Oceanography Command, 1986)
60W
55W
50W
45W

Figure 16.



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Greenland
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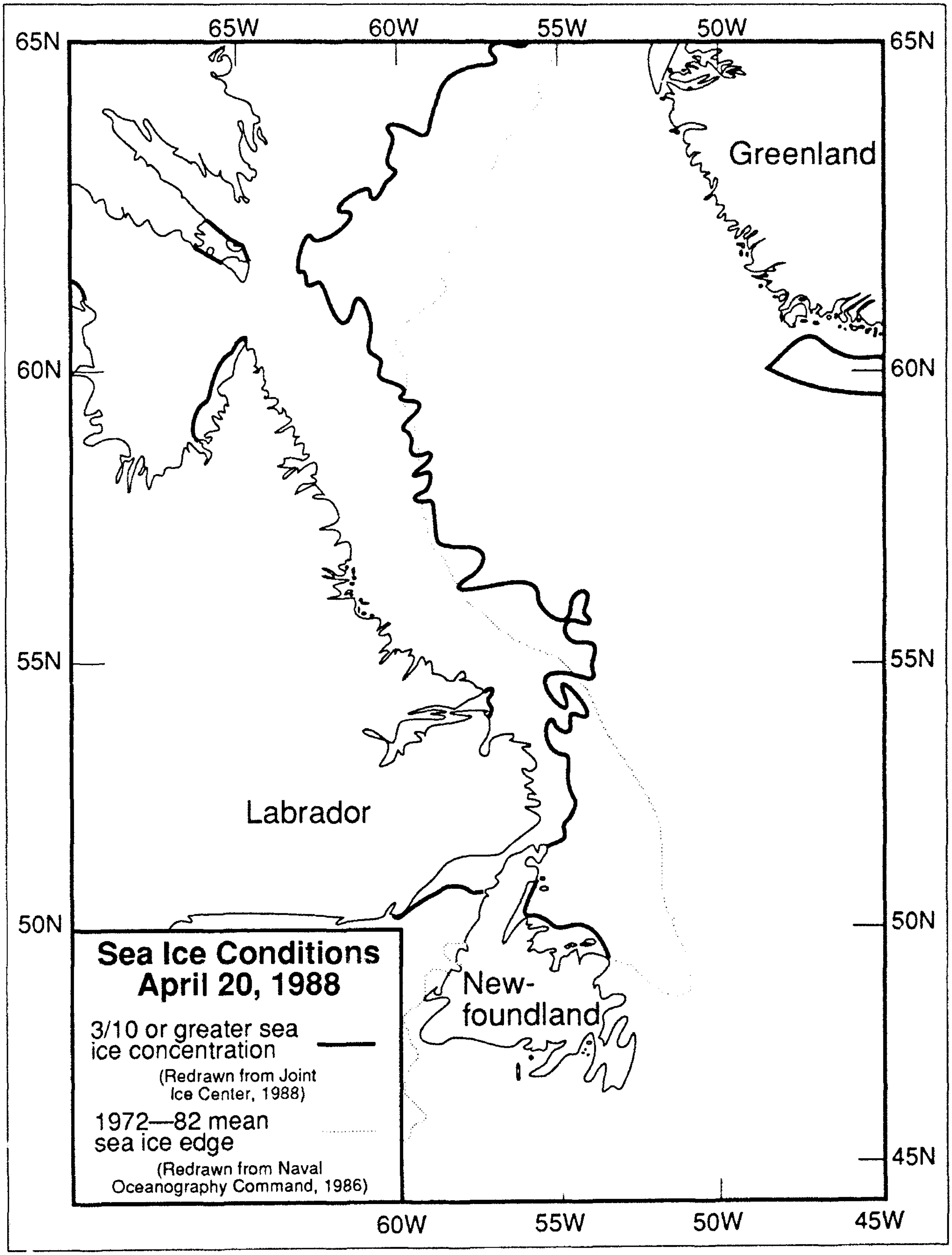
55N
Labrador
50N
50N
Sea Ice Conditions
March 16, 1988
3/10 or greater sea ice concentration
(Redrawn from Joint Ice Center, 1988)
1972—82 mean sea ice edge
(Redrawn from Naval Oceanography Command, 1986)
New-
foundland
45N
60W
55W
50W
45W

Figure 17.



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Greenland
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Labrador
50N
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New-
foundland
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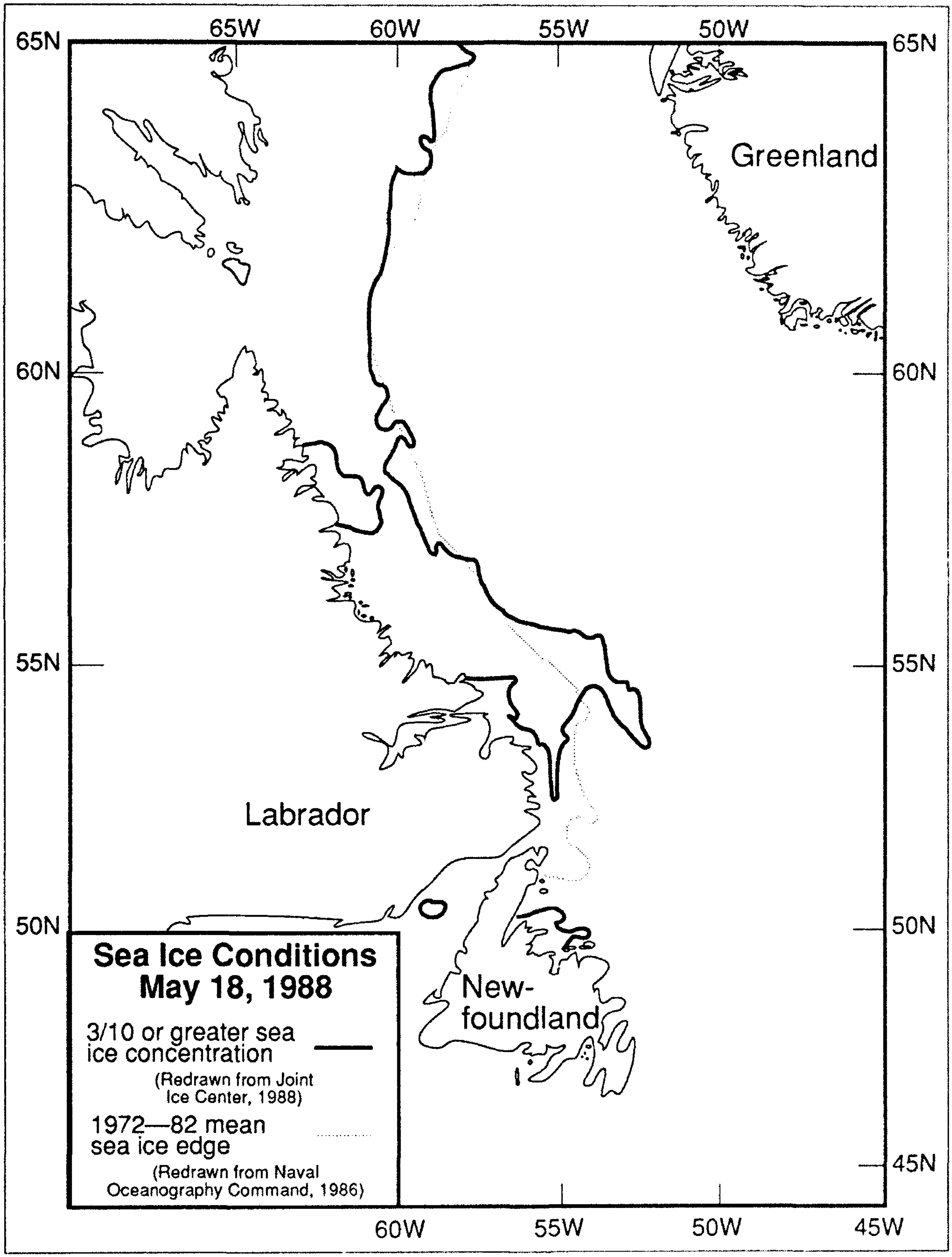
60W
55W
50W
45W
Sea Ice Conditions
April 20, 1988
3/10 or greater sea ice concentration
(Redrawn from Joint Ice Center, 1988)
1972—82 mean sea ice edge
(Redrawn from Naval Oceanography Command, 1986)

Figure 18.



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Greenland
Labrador
New-
foundland
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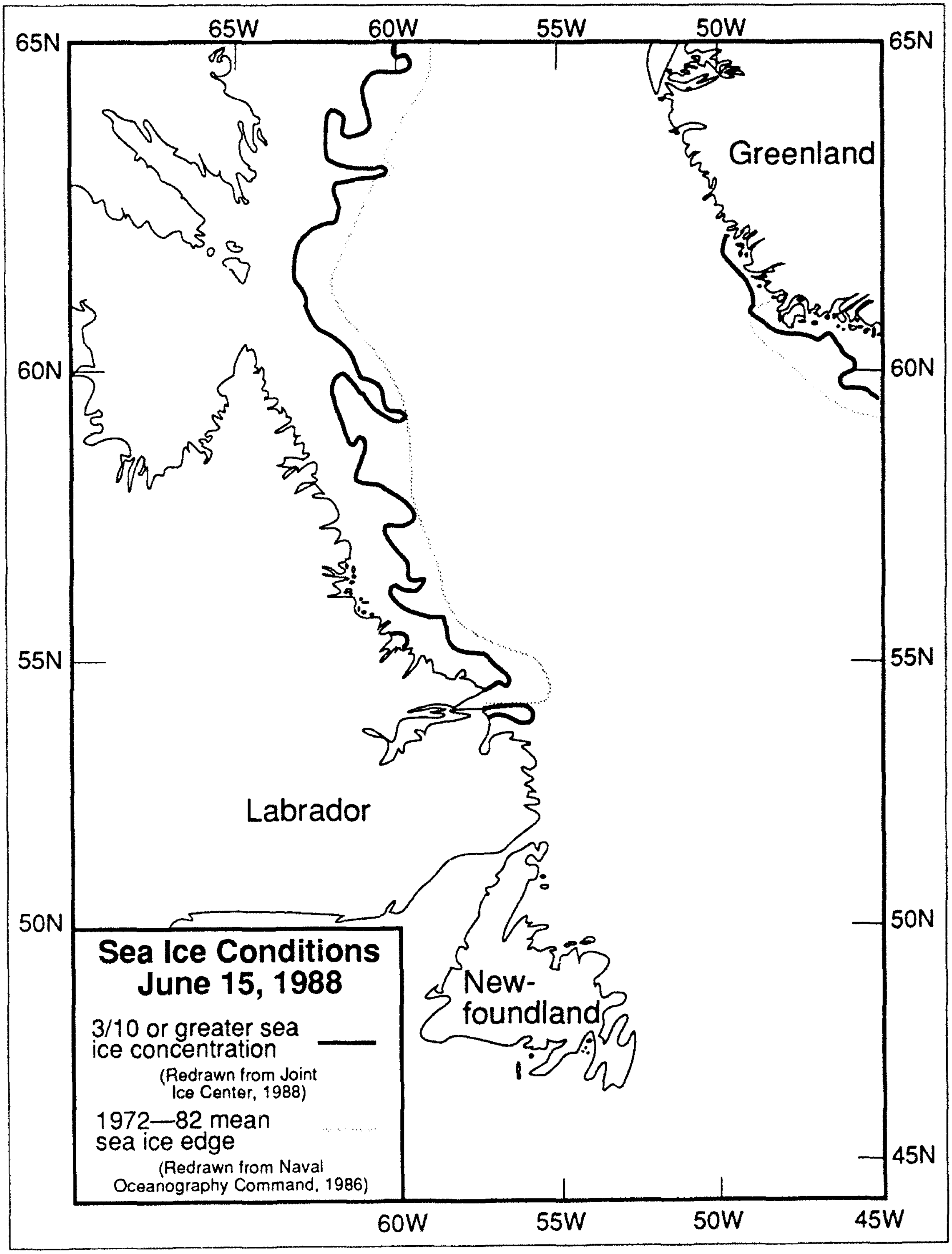
50W
45W
Sea Ice Conditions
May 18, 1988
3/10 or greater sea ice concentration
(Redrawn from Joint Ice Center, 1988)
1972—82 mean sea ice edge
(Redrawn from Naval Oceanography Command, 1986)

Figure 19.



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Greenland
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Labrador
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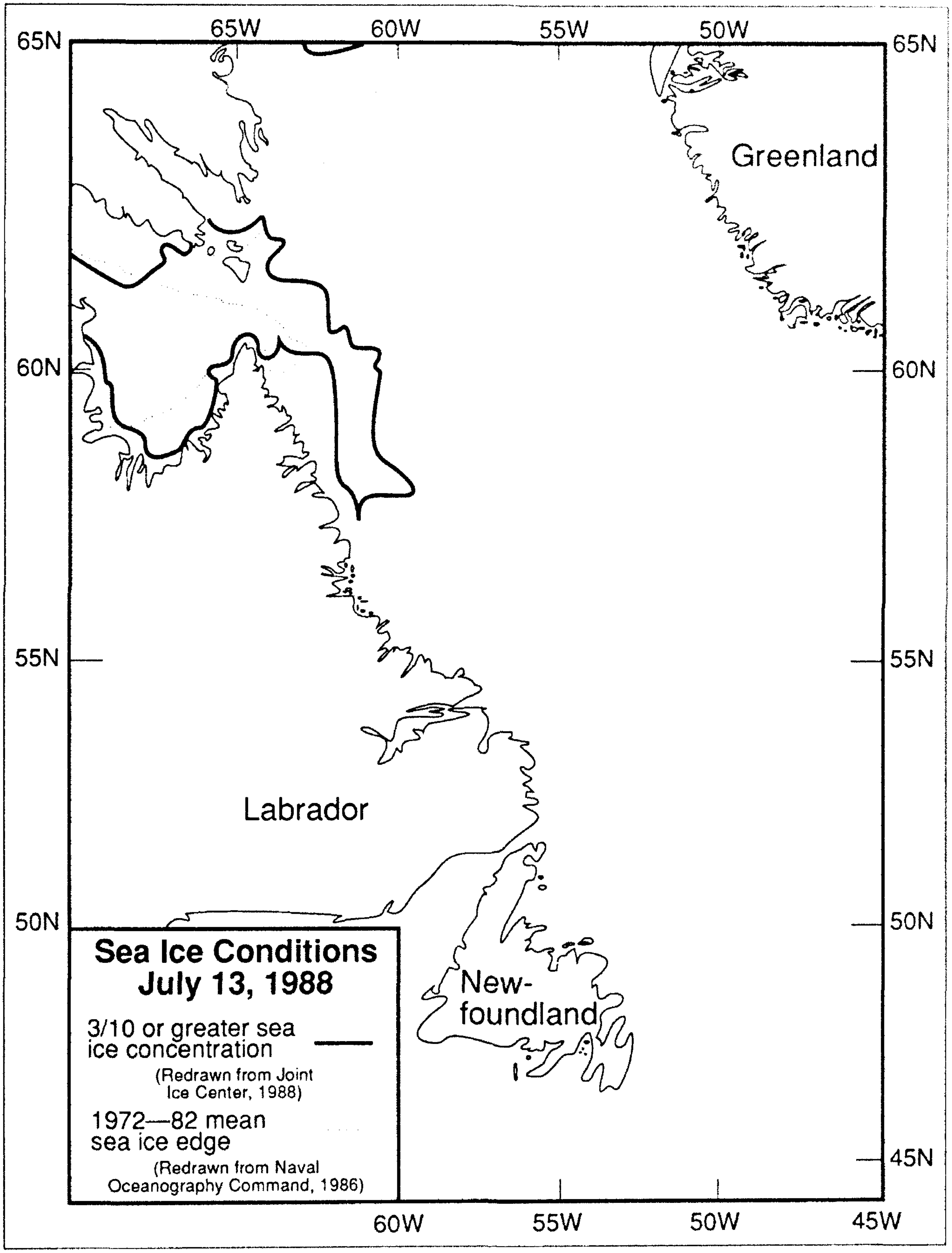
New-
foundland
45N
60W
55W
50W
45W
Sea Ice Conditions
June 15, 1988
3/10 or greater sea ice concentration
(Redrawn from Joint Ice Center, 1988)
1972—82 mean sea ice edge
(Redrawn from Naval Oceanography Command, 1986)

Figure 20.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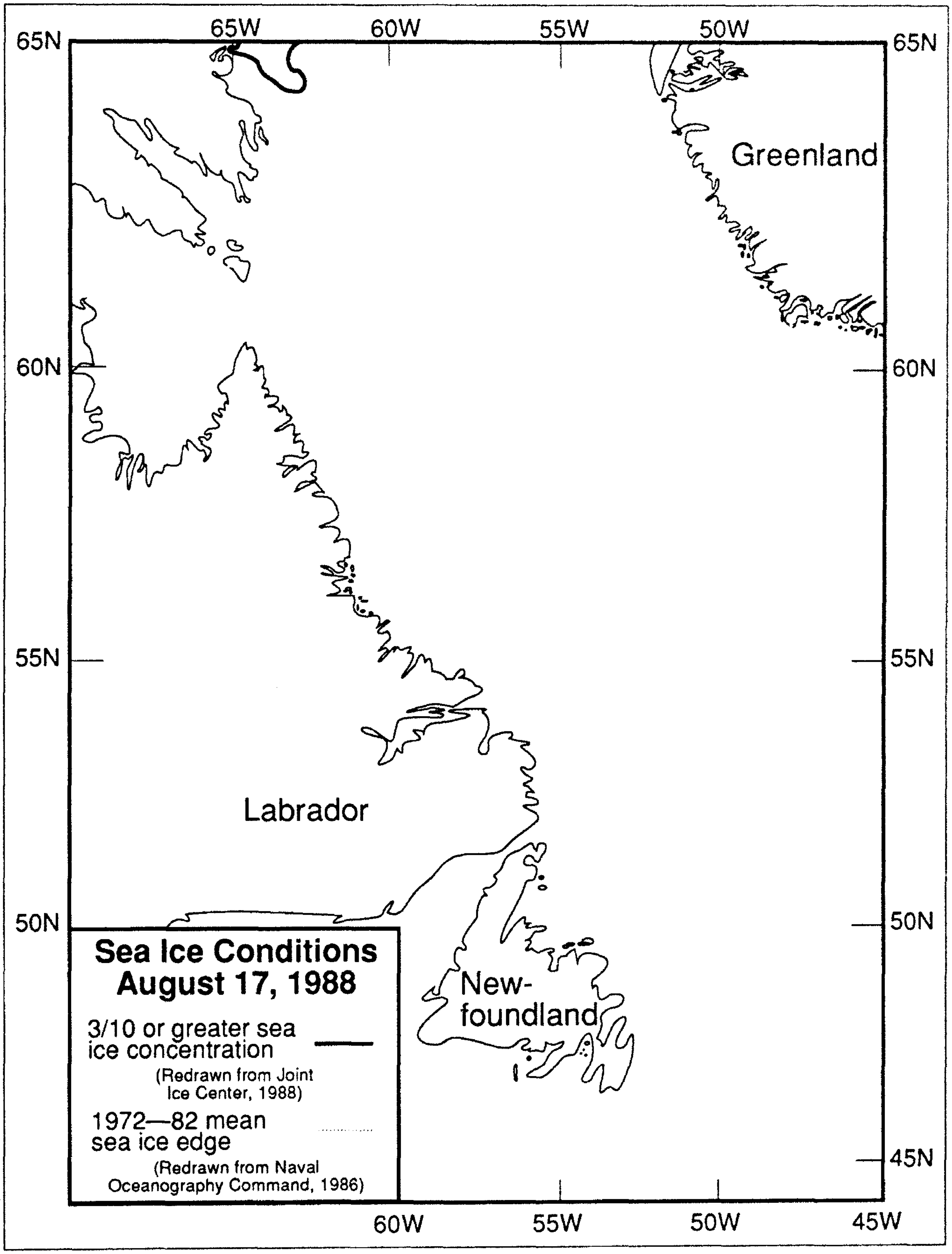
50W
65N
Greenland
60N
60N
55N
55N
Labrador
50N
50N
Sea Ice Conditions
July 13, 1988
3/10 or greater sea ice concentration
(Redrawn from Joint Ice Center, 1988)
1972—82 mean sea ice edge
(Redrawn from Naval Oceanography Command, 1986)
New-foundland
45N
60W
55W
50W
45W

Figure 21.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60W
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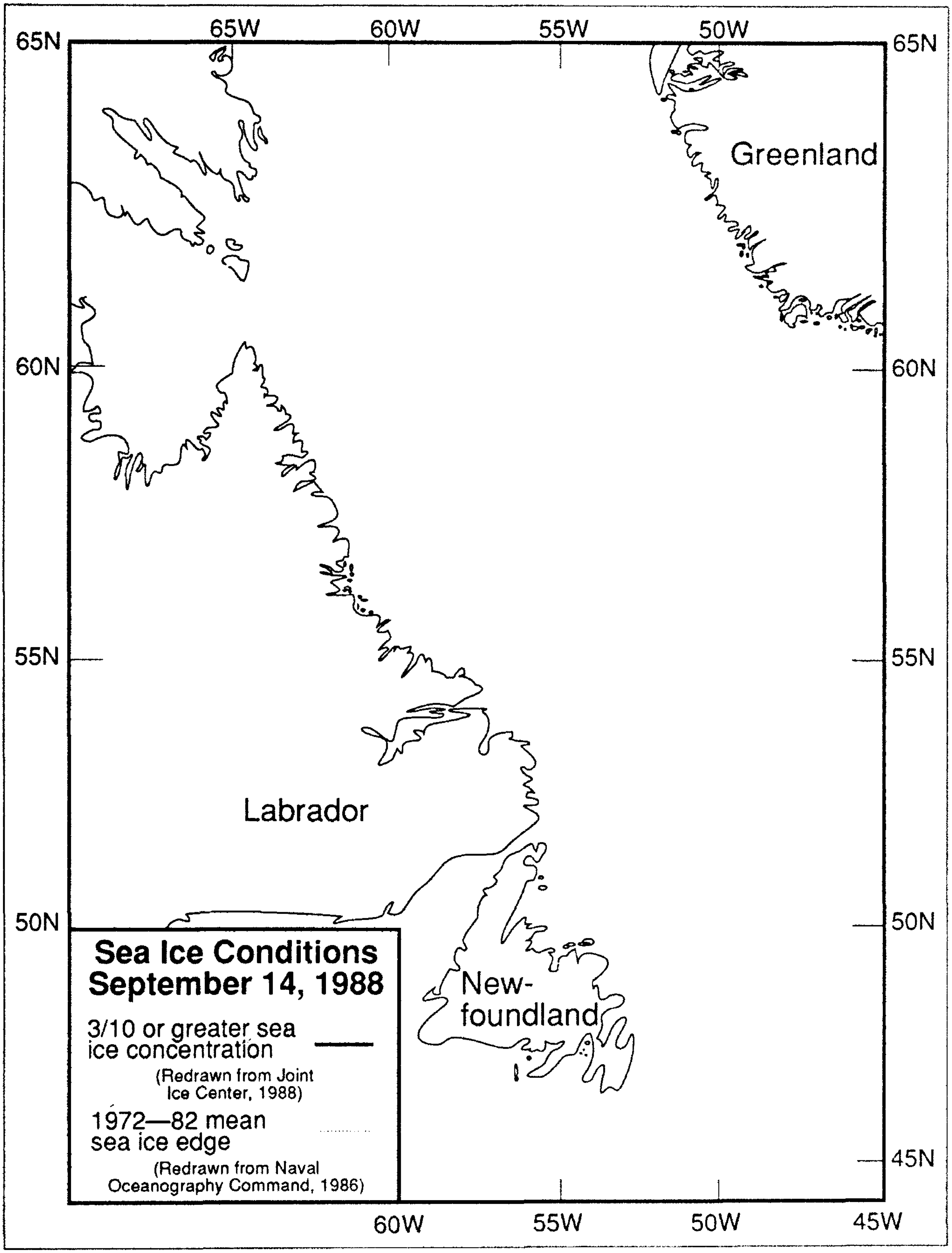
50W
45W
Greenland
Labrador
New-
foundland
Sea Ice Conditions
August 17, 1988
3/10 or greater sea
ice concentration
(Redrawn from Joint
Ice Center, 1988)
1972—82 mean
sea ice edge
(Redrawn from Naval
Oceanography Command, 1986)

Figure 22.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65N
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55N
50N
45N
45W
Greenland
Labrador
New-
foundland
Sea Ice Conditions
September 14, 1988
3/10 or greater sea
ice concentration
(Redrawn from Joint
Ice Center, 1988)
1972—82 mean
sea ice edge
(Redrawn from Naval
Oceanography Command, 1986)

Figure 23. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 13 APR 88 Based On Observed And Forecast Conditions

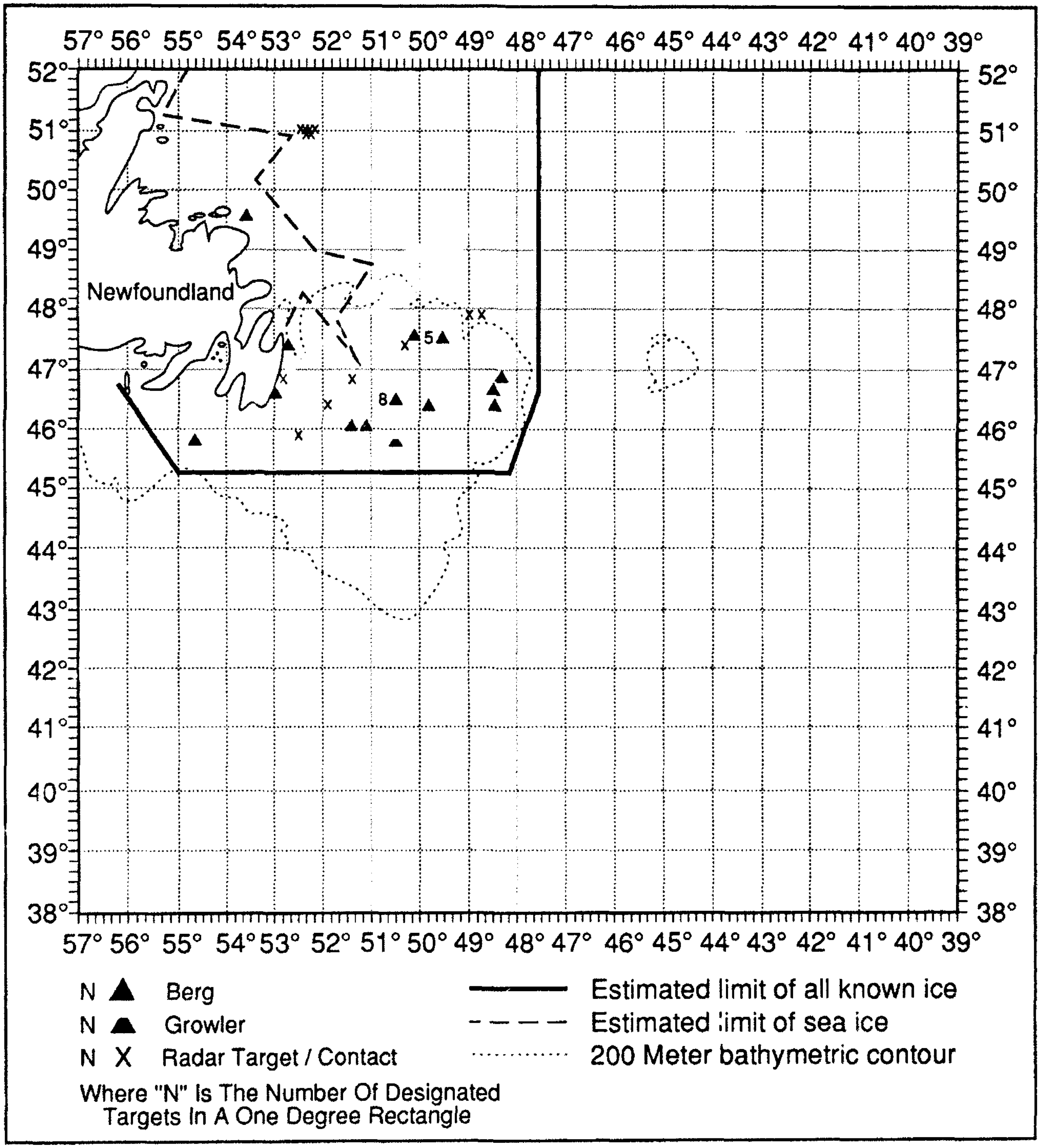


Figure 24. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 15 APR 88 Based On Observed And Forecast Conditions

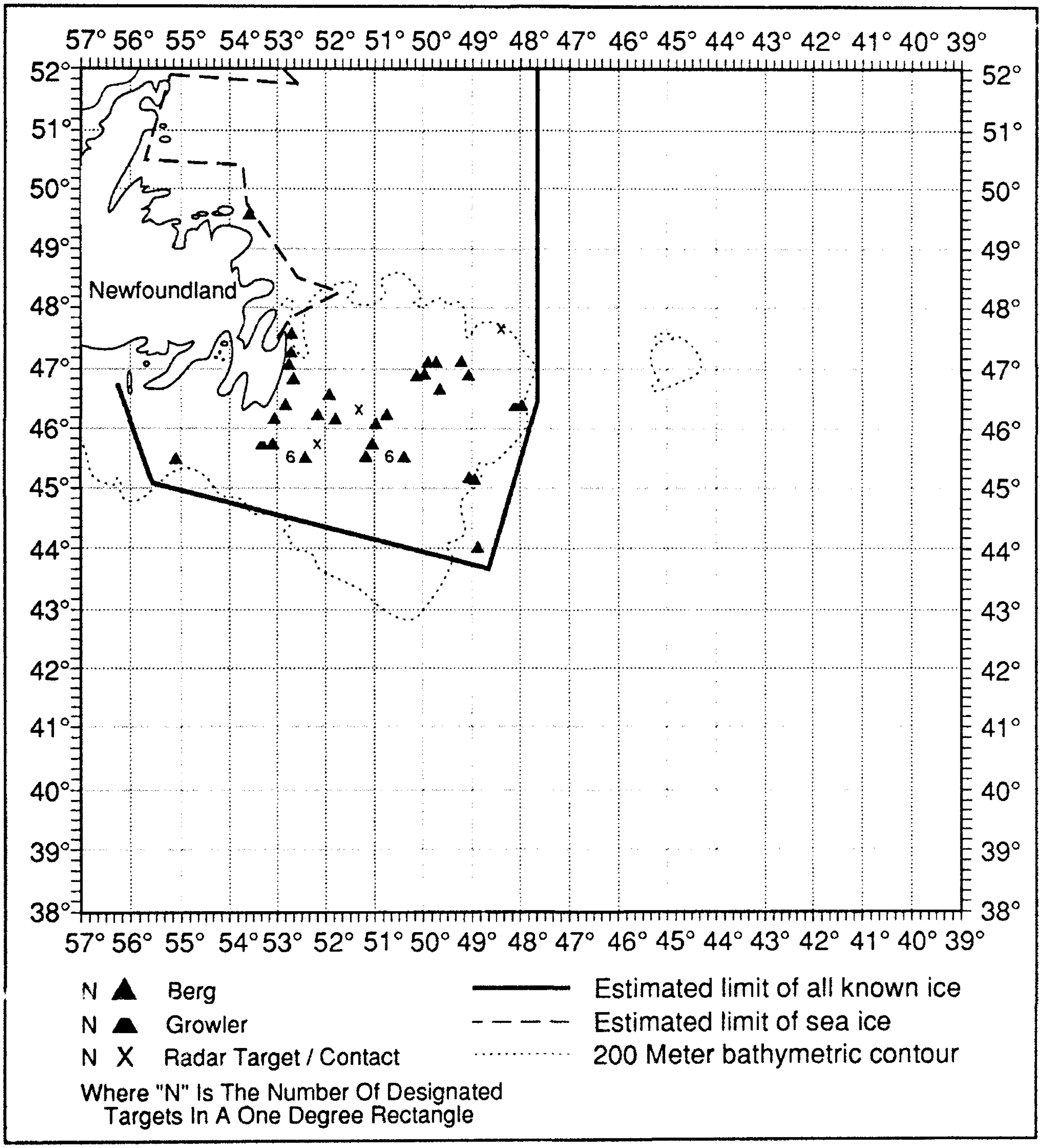


Figure 25. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 30 APR 88 Based On Observed And Forecast Conditions

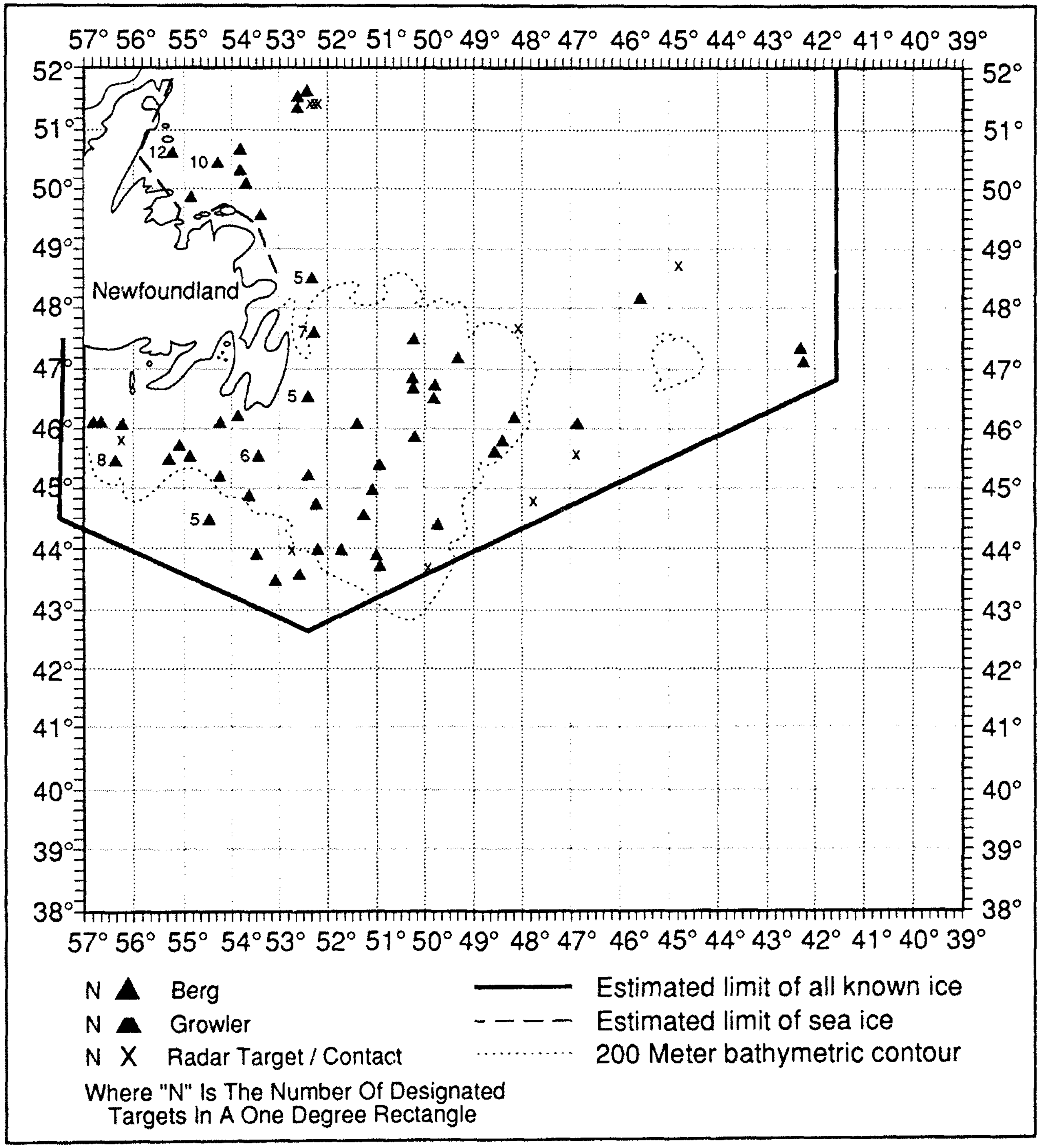


Figure 26. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 15 MAY 88 Based On Observed And Forecast Conditions

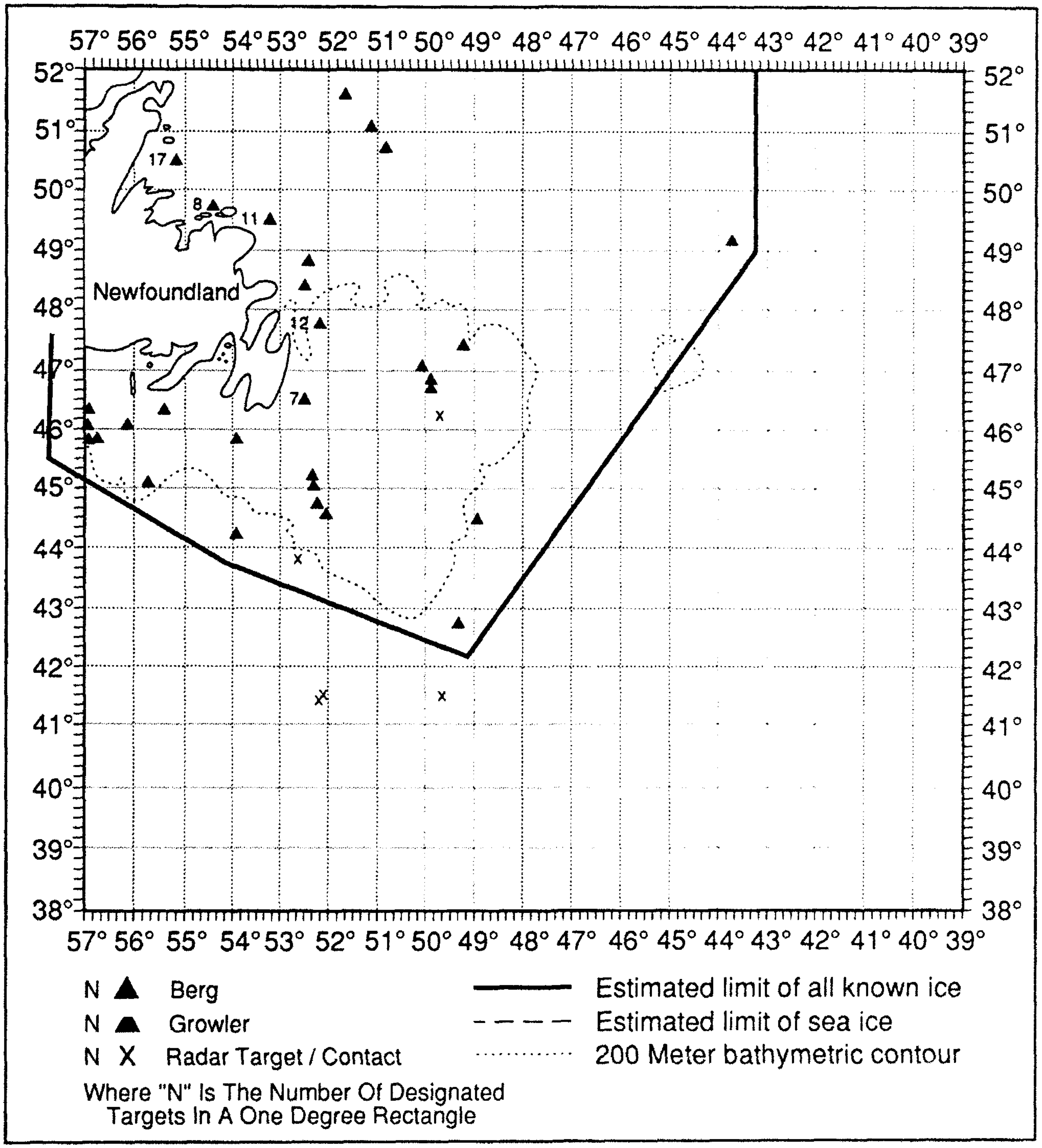


Figure 27. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 30 MAY 88 Based On Observed And Forecast Conditions

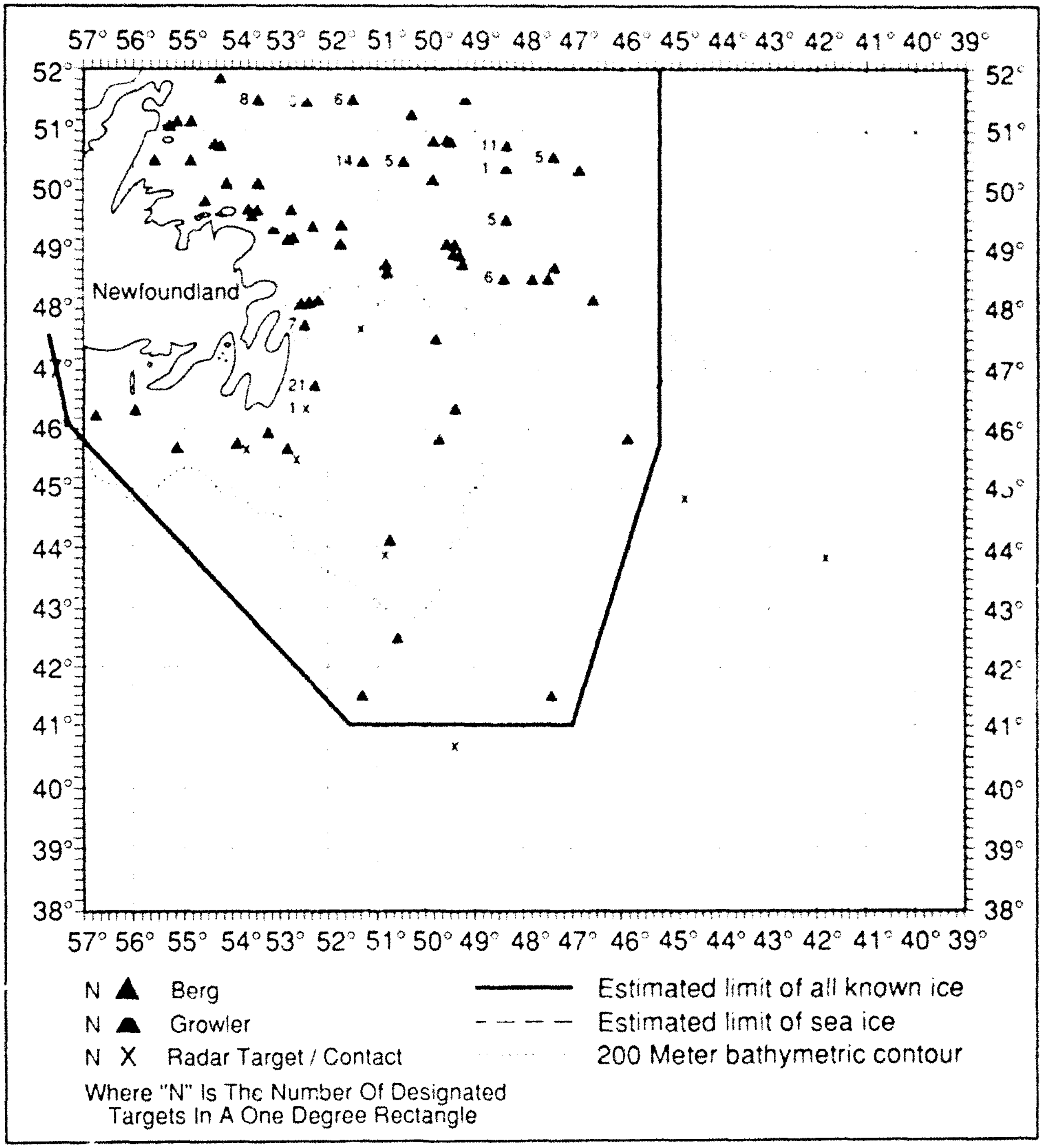


Figure 28. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 15 JUN 88 Based On Observed And Forecast Conditions

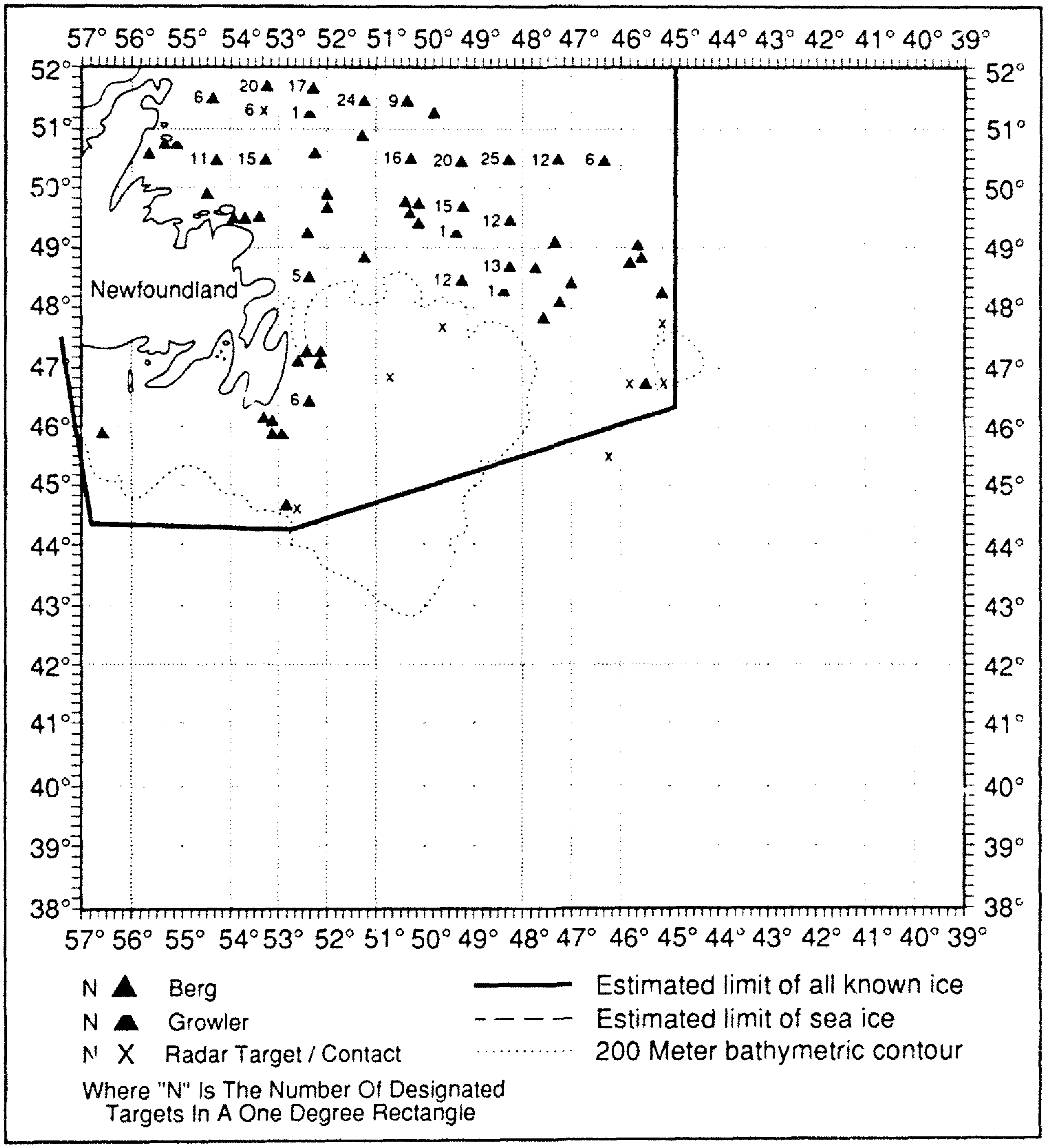


Figure 29. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 30 JUN 88 Based On Observed And Forecast Conditions

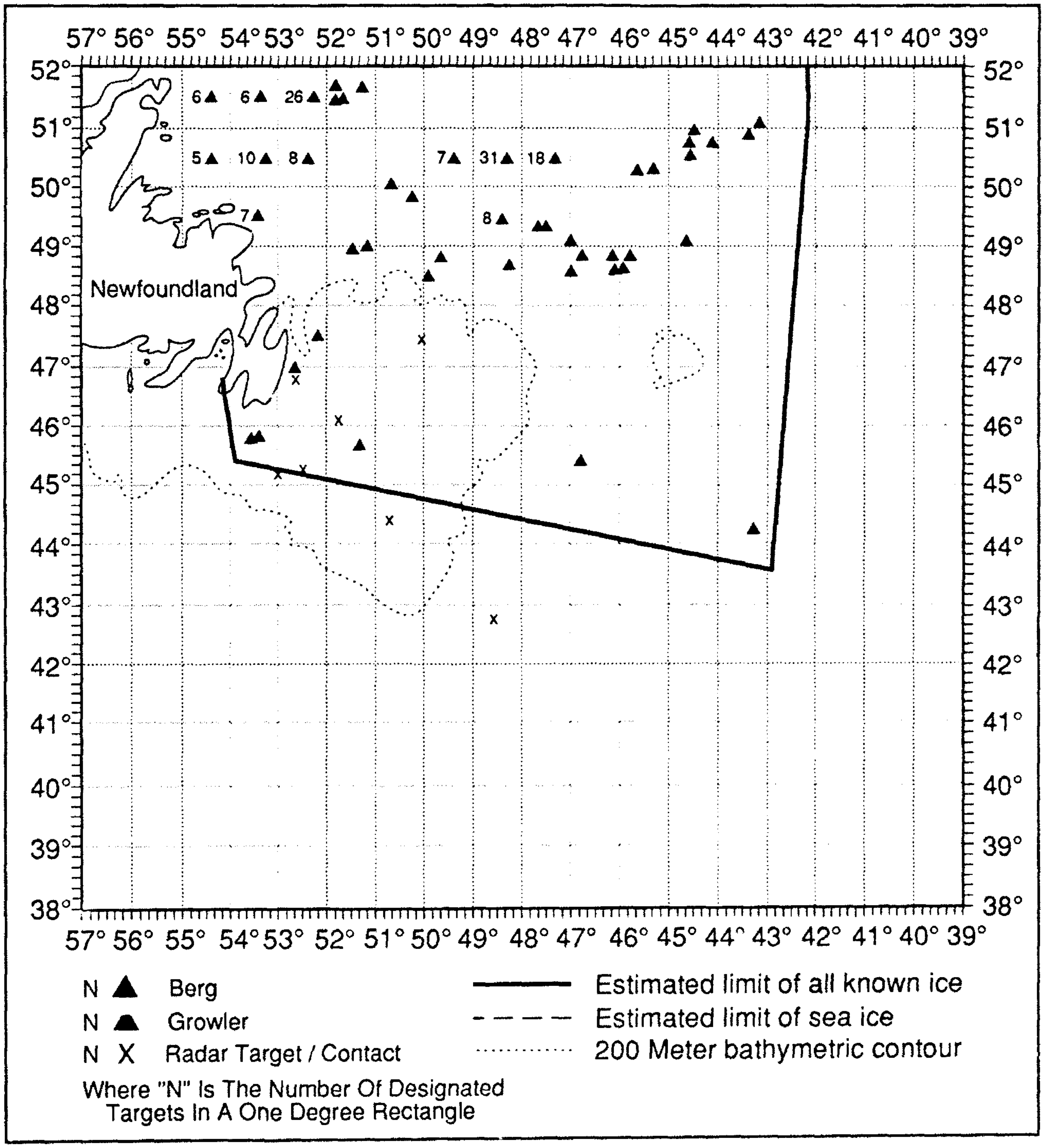


Figure 30. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 15 JUL 88 Based On Observed And Forecast Conditions

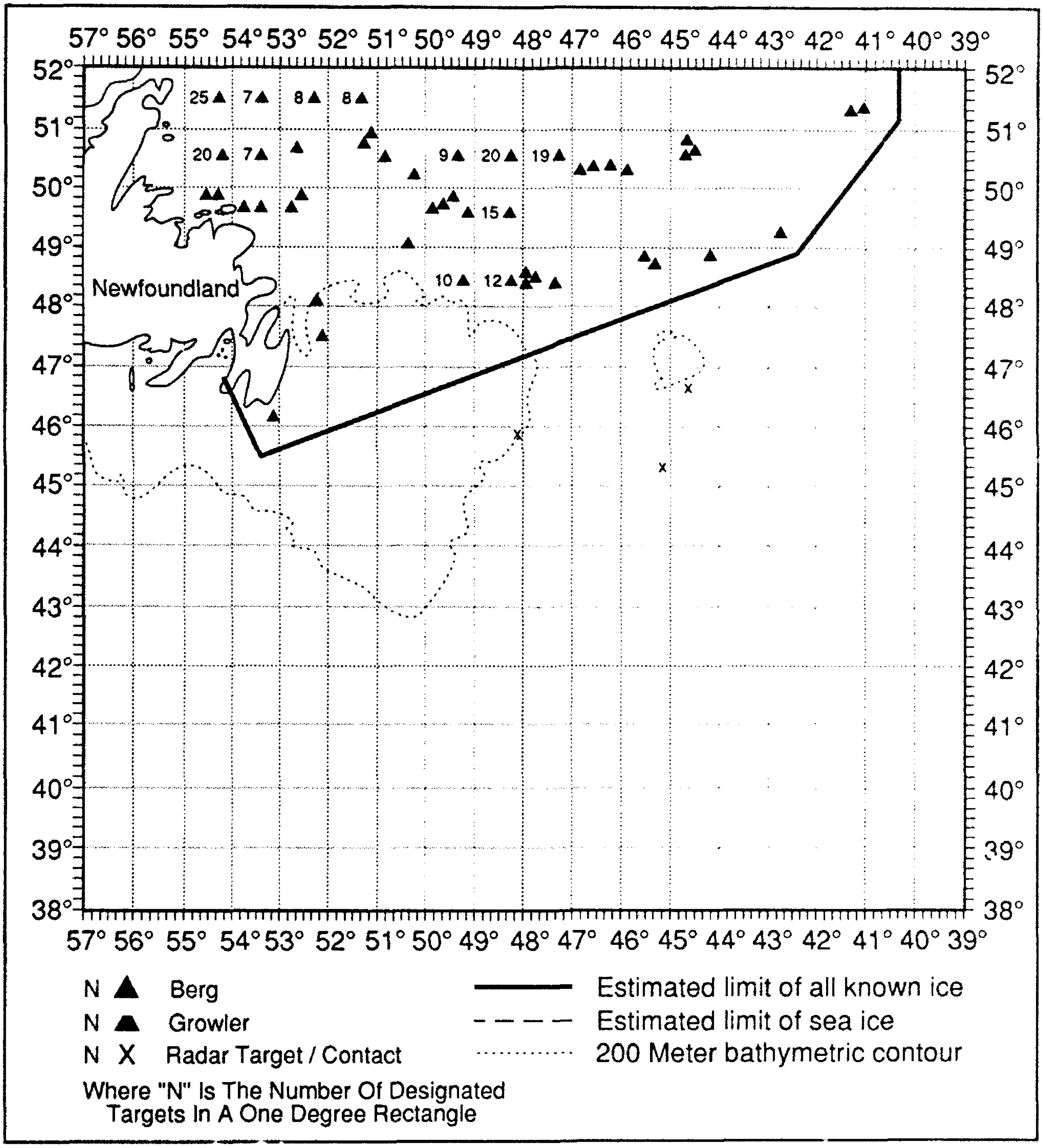


Figure 31. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 30 JUL 88 Based On Observed And Forecast Conditions

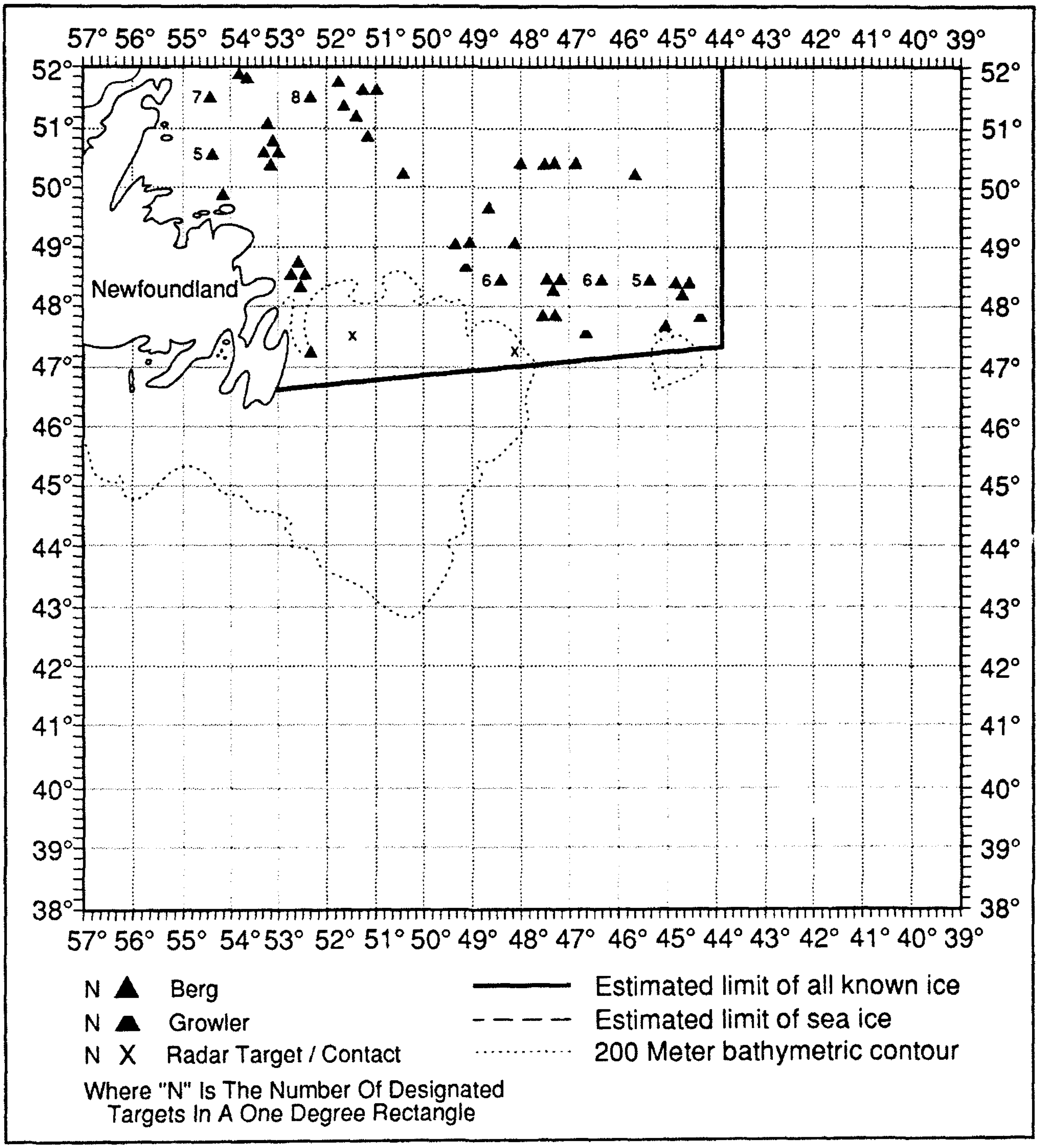
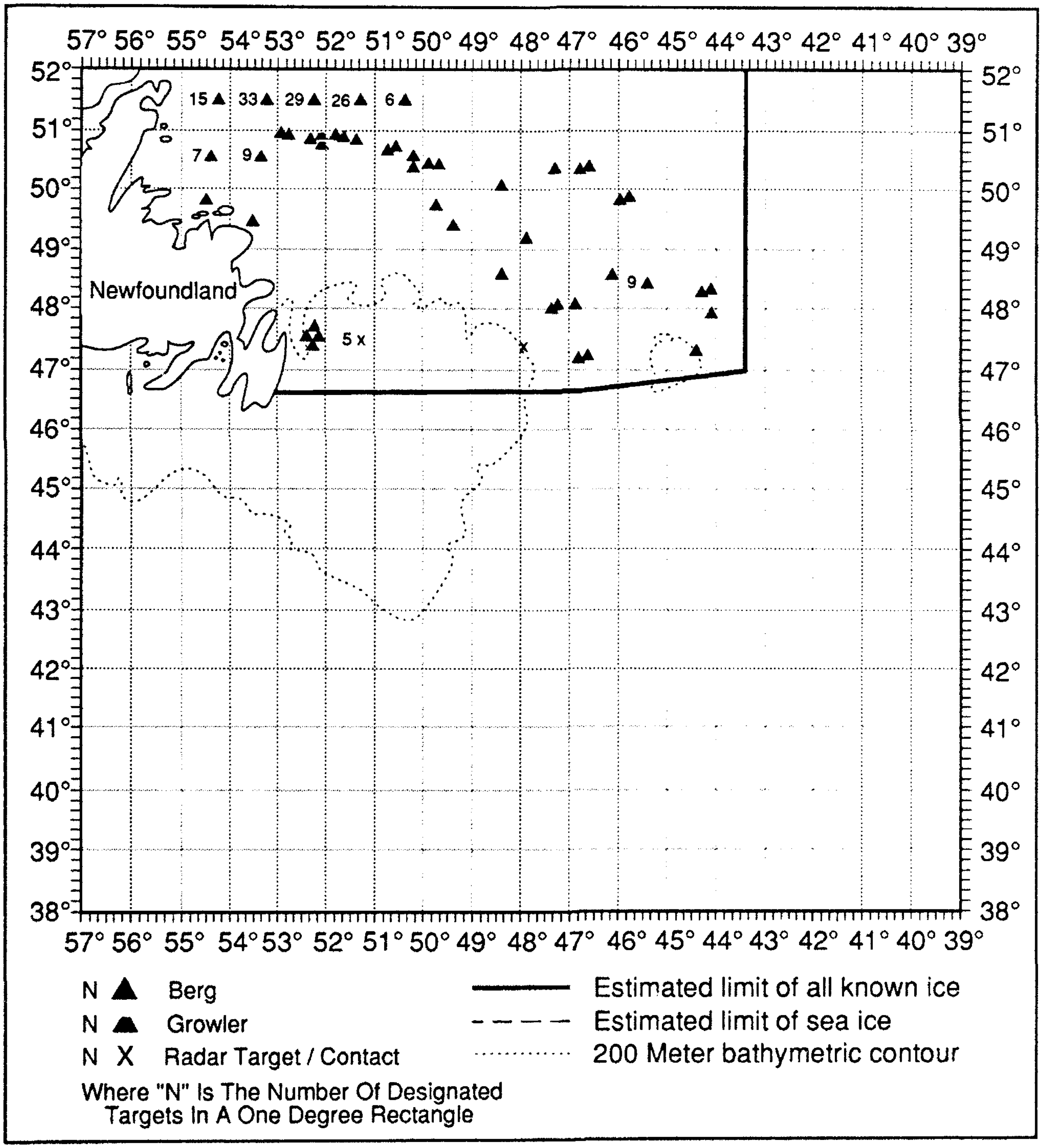


Figure 32. Graphic Depiction Of International Ice Patrol Ice Plot For 1200 GMT 02 AUG 88 Based On Observed And Forecast Conditions



Discussion of Ice and Environmental Conditions

The number of icebergs that pass south of 48°N in the International Ice Patrol area each year is the measure by which International Ice Patrol has judged the severity of each year since 1913 . The average number of icebergs drifting south of 48° N from 1913 to 1987 is 395 (Alfultis, 1987). With 187 icebergs south of 48° N, the 1988 ice year was less severe than the 1913-1987 average.

Since the number of icebergs calved each year by Greenland's glaciers is in excess of 10,000 (Knutson and Neill, 1978), a sufficient number of icebergs exist in Baffin Bay during any year. Therefore, annual fluctuations in the generation of Arctic icebergs is not a significant factor in the number of icebergs passing south of 48°N annually. The factors that determine the number of icebergs passing south of 48°N each season are the supply of icebergs available to drift south onto the Grand Banks, those affecting iceberg transport (currents, winds, and sea ice), and those affecting the rate of iceberg deterioration (wave action, sea surface temperature, and sea ice).

Sea ice acts to impede the transport of icebergs by winds and currents and also protects icebergs from wave action, the major agent of iceberg deterioration. Although it slows current and wind transport of icebergs, sea ice is itself an active medium, for it is continually moving toward the ice edge where melt occurs. Therefore, icebergs in sea ice will eventually reach open water unless grounded. The melting of sea ice itself is affected by snow cover (which slows melting) and air and sea water temperatures. As sea ice melt accelerates in the spring and early summer, trapped icebergs are rapidly released and then become subject to normal transport and deterioration.

The Labrador Current, aided by northwesterly winds in winter, is the main mechanism transporting icebergs south to the Grand Banks. In addition to transporting icebergs south, the relatively cold waters of the Labrador current keep the deterioration of icebergs in transit to a minimum.

The 1988 International Ice Patrol season did not open until mid-April because of the small number of icebergs drifting south of 52° or 48° N in January, February, and March. With the sea ice not extending as far south as normal in February and March, the icebergs were not protected as long from deterioration. The below average sea ice conditions at the beginning of the season would normally lead to a relatively light ice season with a late start.

Beginning in April and continuing through August, large numbers of icebergs began to drift south of 52° N and enter IIP's area. There was a good supply of icebergs available to drift south of 48° N from April to August, but the environmental and oceanographic conditions were not favorable for the southward drift of icebergs. Most of these icebergs did not drift south with the Labrador Current to the Tail of the Grand Banks, but drifted east. By July and August, iceberg deterioration became a major factor preventing icebergs from surviving a drift south of 48° N. In summary, it appears the environmental and oceanographic conditions set up an unfavorable eastward drift, preventing the large number of icebergs entering IIP's area from drifting south of 48° N with the Labrador Current.

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It is also important to recognize the effons of the personnel at the International Ice Patrol: CDR S. R. Osmer, LCDR W. A. Hanson, Dr. D. L. Murphy, LCDR R.L. Tuxhorn, LT N. B. Thayer, LT M. A. *Alfultis*, MSTCS G. F. Wright, MSTC M. F. Alles, YN1 P. G. Thibodeau, MST1 M. G. Barrett, MST1 C. R. Moberg, MST2 J. L. Perdue, MST2 J. R. Shubert, MST2 D. D. Beebe, MST2 D. A. Hutchinson, MST2 J. C. Myers, MST3 M. E. Petrick, MST3 P. B. Reilley, MST3 R. C. Lenfenstey, MST3 N. A. Capobianco, MST3 M. D. Baechler, and MST3 C. F. Weiller.

Appendix A
List of Participating Vessels, 1988

VESSEL NAME	FLAG	SST	ICE REPORTS
ABITIBI CLARBORNE	FED. REP. OF GERMANY		9
ABITIBI CONCORD	FED. REP. OF GERMANY		8
ABITIBI MACADO	FED. REP. OF GERMANY		4
ABITIBI ORINOCO	FED. REP. OF GERMANY		3
ADA GORTHON	SWEDEN		1
ADITYA KIRAN	INDIA		1
AIGIANIS	GREECE		3
AILSA	LIBERIA		2
ALBRIGHT PIONEER	UNITED KINGDOM		1
ALCYONE	FRANCE		1
ALFRED NEEDLER	CANADA		1
ALMARE TERZA	ITALY	5	1
ALTA	LIBERIA		1
ALUK	DENMARK		1
ANDROMEDA	POLAND		1
ANN HARVEY	CANADA		6
ANNA	ST. VINCENT AND THE GRENADINES	7	
APILIOTIS	GREECE		1
ARC MINOS	GREECE		1
ARCTIC	CANADA		1
ARIES	CYPRUS		1
ATLANTIC AMITY	UNITED KINGDOM		1
ATLANTIC CARTIER	FRANCE		1
ATLANTIC CONVEYOR	UNITED KINGDOM		2
ATLANTIC OLGA	CANADA		1
ATLANTIC QUEEN	U. S. A.		2
AVALON HARVESTER	UNKNOWN		1
BAFFIN	CANADA		1
BAKKAFOSS	BAHAMAS		4
BALTIC	CYPRUS		2
BARDU	NORWAY		2
BELLE ISLE	FRANCE		1
BENIER	UNKNOWN		1
BENNY SKOU	DENMARK		1
BEVERLY FAYE	CANADA		1

SST = SEA SURFACE TEMPERATURE

VESSEL NAME	FLAG	SST	ICE REPORTS
BIJELO POLJE	YUGOSLAVIA		1
BLUE BIRD	FED. REP. OF GERMANY		1
BOE SEA	PANAMA		1
BONAVISTA BAY	CANADA		4
BOWDRILL 3	CANADA		4
BRAE TRADER	LIBERIA		1
BRIDGEWATER	FED. REP. OF GERMANY		2
BRITISH STEEL	UNITED KINGDOM		2
CANADIAN EXPLORER	UNITED KINGDOM		5
CANMAR AMBASSADOR	UNITED KINGDOM		14
CANMAR EUROPE	BELGIUM		16
CANMAR SPIRIT	PANAMA		2
CAPE ROGER	CANADA		5
CAPE SOUNION	GREECE		1
CARMEN	SWEDEN		1
CAST CARIBOU	LIBERIA	7	2
CAST HUSKY	BAHAMAS	3	7
CAST MUSKOX	BAHAMAS		3
CAST OTTER	BAHAMAS		2
CAST POLARBEAR	LIBERIA		2
CAVALLO	CANADA		3
CECELIEA DESGAGNES	CANADA		1
CHARLOTTE BASTIAN	FED. REP. OF GERMANY		2
CHESAPEAKE BAY	U.S.A.		1
CHIMO	UNITED KINGDOM	5	4
CHIPPEWA	LIBERIA		1
CICERO	CANADA		1
COLORADO	U. S. A.	3	3
COMMANDANT GUE	FRANCE		1
COMPANION EXPRESS	SWEDEN		2
DART ATLANTIC	LIBERIA		1
DELPHINUS	ITALY	7	9
DES CHESNES	UNKNOWN		1
DISKO	DENMARK		1
DODSLANDE	LIBERIA	2	6

VESSEL NAME	FLAG	SST	ICE REPORTS
DUKE OF TOPSAIL	UNITED KINGDOM		1
DUSSELDORF EXPRESS	FED. REP. OF GERMANY		1
EASTERN TRADER	PEOPLES REP. OF CHINA	18	5
EASTERN UNICORN	PANAMA		1
ENERCHEM FUSION	CANADA		2
ESTE SUBMERGER	FED. REP. OF GERMANY	2	
EVER GOIN	PANAMA		1
EXXON SAN FRANCISCO	U. S. A.		1
FALCON	NORWAY		3
FALMOUTH	GREECE		1
FARQUHARSON	UNKNOWN	10	7
FATIMA C	PANAMA	10	11
FEDERAL DANUBE	CYPRUS		3
FEDERAL ELBE	LIBERIA		1
FEDERAL MAAS	CYPRUS	4	4
FEDERAL OTTAWA	BELGIUM		3
FEDERAL SAGUENAY	LIBERIA		2
FEDERAL SCHELDE	LIBERIA		1
FEDERAL ST CLAIR	LIBERIA		4
FEDERAL THAMES	CYPRUS		3
FERMEUSE	CANADA		2
FIGARO	CYPRUS	5	
FINNFIGHTER	FINLAND		3
FINNPOLARIS	FINLAND	5	3
FLYING DART	CANADA		1
FOGO ISLE	CANADA		1
FRITHJOF	FED. REP. OF GERMANY		1
FULLNESS	LIBERIA		2
FURIA	LIBERIA		1
GABARUS BAY	CANADA		6
GATTINEAU	UNKNOWN		1
GRAND BARON	CANADA		1
GRETE THERESA	DENMARK		8
GULF GRAIN	LIBERIA	7	7
HARITAS	CYPRUS	5	

VESSEL NAME	FLAG	SST	ICE REPORTS
HARP	CANADA		9
HELENA OLDENDORFF	PANAMA		2
HERCE GOVINA	YUGOSLAVIA	7	
HOFJOKULL	ICELAND		2
HOLCAN MAAS	GREECE	1	3
HOLCAN RIJN	CYPRUS		7
HOOD	CANADA		1
HUDSON	CANADA		6
HYPHESTOS	GREECE		1
ICE FLOWER	DENMARK		3
ICE PEARL	DENMARK		6
ICEBLINK	DENMARK		8
IMPERIAL BEDFORD	CANADA		1
IMPERIAL ST CLAIRE	CANADA		1
IRON MASTER	PANAMA		5
IRONBRIDGE	UNITED KINGDOM		1
IROQUOIS	PHILIPPINES		1
IRVING NORDIC	CANADA		5
IRVING OURS POLAIRE	CANADA		7
J.C. PHILLIPS	CANADA		1
JACKMAN	CANADA		5
JACUHY	BRAZIL		1
JOH GORTSON	SWEDEN		2
JOHAN PETERSEN	DENMARK		8
JOHANNA KRISTINA	GREENLAND		6
JOHN CABOT	CANADA		5
KAETHE HUSMANN	FED. REP. OF GERMANY		1
KANGUK	CANADA		2
KAREN WINTHER	DENMARK		1
KAZIMIERZ PULASKI	POLAND		2
KHUDOZHNIK REPIN	U. S. S. R.		3
KOMSOMOLETS ESTONII	U. S. S. R.		1
KONGAR INTREPID	GREECE		2
KUNUNGUAK	DENMARK		3
LA CHESNAIS	FRANCE	4	

VESSEL NAME	FLAG	SST	ICE REPORTS
LA PLATA MARU	CUBA		1
LA RICHARDIAS	FRANCE		6
LACKENBY	UNITED KINGDOM		5
LE SAULE	CANADA		1
LEGER	CANADA		1
LEONARD J COWLEY	CANADA		10
LIEPAYA	U. S. S. R.		1
LONE VENTURE	UNKNOWN		1
LUGANO	SWITZERLAND		1
LUNNI	FINLAND		10
LYNCH	U. S. A.	3	4
MADZY	SWEDEN		1
MAGNUS JENSEN	DENMARK		7
MALINSKA	YUGOSLAVIA		5
MALOJA 2	SWITZERLAND		6
MALVINA	CYPRUS		1
MANCHESTER CHALLENGER	UNITED KINGDOM		4
MARGARITA	CANADA		2
MARIA GORTHON	SWEDEN		1
MARINE PACKER	CANADA		1
MARKA L	GREECE		1
MAXWELL	CANADA		1
MELA	PANAMA		1
MIHALIS	GREECE		1
MINERVA	LIBERIA		1
NAJA ITTUK	DENMARK		8
NATHALIE DON II	UNKNOWN		1
NATSEK	GREENLAND		1
NAUTICAL ENTERPRISE	UNKNOWN		1
NAVIOS VALOR	LIBERIA		2
NEDLLOYD HUDSON	U. S. A.		1
NEPTUNE PERIDOT	SINGAPORE		4
NEW INDEPENDENCE	LIBERIA		1
NEWFOUNDLAND FALCON	CANADA		2
NIKKI ITTUK	DENMARK		15

VESSEL NAME	FLAG	SST	ICE REPORTS
NIN	YUGOSLAVIA		2
NIVI ITTI'K	DENMARK		9
NORDIC SUN	LIBERIA		3
NORLANDIA	FED. REP. OF GERMANY		10
NORTHERN CHERRY	POLAND		1
NORTHERN EXPRESS	NETHERLANDS		3
NORTHWIND	U. S. A.	14	15
NOSIRA SHARON	UNITED KINGDOM		1
NUKA ITTUK	DENMARK		7
NUNGU ITTUK	DENMARK	2	20
NURNBERG ATLANTIC	FED. REP. OF GERMANY		1
OCEAN TRAVELLER	SINGAPORE		3
OLYMPIC MERIT	PANAMA		2
ONTADOC	CANADA		2
PACIFIC CONFIDENCE	PANAMA		1
PACIFIC EXPRESS	LIBERIA		1
PACIFIC PRESTIGE	UNITED KINGDOM		1
PACIFIC PROMINENCE	UNITED KINGDOM		1
PAN MAPLE	GREECE		1
PETKA	YUGOSLAVIA	5	4
PETROLAB	CANADA		4
PLACENTIA BAY	CANADA		2
PLANET	BAHAMAS	1	3
POINTE DE CORSEN	FRANCE		1
POLAR NANOQ	DENMARK		5
POLY CRUSADOR	NORWAY		1
POLY SUNRISE	NORWAY		1
POMORZE ZACHODNIE	POLAND		2
PROJECT ORIENT	NETHERLANDS ANTILLES		3
PUMA	JAPAN	7	
QUEEN ELIZABETH II	UNITED KINGDOM	1	1
RADNIK	PANAMA		1
RAVENNA	PANAMA		6
ROBERT MAERSK	DENMARK	2	2
ROSS R	CANADA		1

VESSEL NAME	FLAG	SST	ICE REPORTS
SAINT CONSTANTINOS	LIBERIA	6	
SAINT LAURENT	PANAMA		1
SAINT LUCIA	LIBERIA		2
SANO R	DENMARK		1
SANTAN	PHILIPPINES	3	1
SASKETCHEWAN PIONEER	CANADA		1
SAULE NO 1	U. S. S. R.		1
SEA HAWK	U. S. A.		1
SEALAND CONSUMER	U. S. A.	1	1
SEDCO 710	CANADA		2
SELKIRK SETTLER	CANADA		2
SIR JOHN FRANKLIN	CANADA	1	1
SIR ROBERT BOND	CANADA		1
SIR WILFRED GRENFELL	CANADA		4
SKEENA	UNITED KINGDOM	3	2
SKIDEGATE	CANADA		1
SLETHAV	NORWAY		1
SPRAY TANAO	PHILIPPINES		1
SPRAYNES	PANAMA	5	2
STOLT ASPIRATION	PANAMA		2
STOLT BOEL	LIBERIA		1
STOLT CROWN	LIBERIA		2
STRAITS PRIDE	SINGAPORE		1
STRATHCONAN	UNITED KINGDOM		1
SVANUR	ICELAND		1
TADEUSZ KOSCIUSZKO	POLAND		2
TAURIA	CYPRUS		1
TEVERA	CYPRUS		4
TEXACO WESTMINISTER	UNITED KINGDOM		3
TEXAS CLIPPER	U. S. A.		3
THEOGENNITOR	CYPRUS		1
TNT EXPRESS	AUSTRALIA		1
TOKACHI MARU	JAPAN	4	4
TORM GUNHILD	DENMARK		4
TORNADO	POLAND	1	1

VESSEL NAME	FLAG	SST	ICE REPORTS
TORONTO	BERMUDA		1
TOSA MARU	JAPAN		2
TRACKER 1	CANADA		1
TRIUMPH SEA	CANADA		7
VAIR	CANADA		1
VARJAKKA	BAHAMAS		1
VICTOR BUGAEV	U. S. S. R.		1
VIGILANT	UNITED KINGDOM	1	1
VISHA PARIJAT	INDIA	2	3
VROUWE JOHANNA	NETHERLANDS	1	5
WHITE SEA	SINGAPORE		1
WILFRED TEMPLEMAN	CANADA		1
ZAMBESI	CANADA		1
ZANDBERG	CANADA		5
ZEILA	CANADA		1
ZEVEN	CANADA		1
ZIEMIA SUWALSKA	POLAND		1
ZONNEMARIE	CANADA		2

Appendix B

International Ice Patrol's 1988 Drifting Buoy Program

Donald L. Murphy

INTRODUCTION

The 1988 iceberg season was the thirteenth consecutive year that the International Ice Patrol (IIP) has used satellite-tracked buoys to measure currents in its operations area in the western North Atlantic Ocean. The buoy trajectories are used to provide near realtime current data to the Ice Patrol iceberg drift model. These currents are used to modify the mean currents temporarily in the region through which the buoy is moving. Shortly after a buoy departs the region, the current reverts to its mean value.

During 1988 Ice Patrol deployed eleven buoys, six for operational use and five as part of an evaluation of a new buoy type. Of the six operational buoys, five provided excellent data. One buoy failed on deployment.

The 1988 drifting buoy program was unique in two ways. First, it marked the first time that all of the operational buoys were recovered and returned to Ice Patrol at the conclusion of the season. Second, it was the first time that Ice Patrol deployed mini-drifting buoys during its season. In all, Ice Patrol reconnaissance aircraft deployed five mini-drifters, four in cooperation with the U.S. Navy and one with the Canadian Atmospheric Environment Service (AES).

The standard configuration for the operational buoys is a 3 meter long spar hull with a 1 meter diameter flotation collar. Each buoy was equipped with a 2 by 10 meter window-shade drogue attached to the buoy with a 50 meter tether of 1/2" (1.3 cm) nylon. The center of the drogue was at a nominal depth of 58 m. In addition, each buoy had a temperature sensor mounted approximately 1 m below the waterline, a drogue tension monitor, and a battery voltage monitor. The sea surface temperature is accurate to approximately 1°C.

The data from the buoys are acquired and processed by Service ARGOS. Ice Patrol queries the ARGOS data files and stores the buoy data once daily. Most of the buoy position data fall within the standard accuracy provided by Service ARGOS (~350 m). All of the buoy data were entered onto the Global Telecommunications System (GTS). Each buoy is assigned a World Meteorological Organization (WMO) number.

Table B-1 summarizes the 1988 buoy deployments.

Table B-1. Summary of 1988 Deployments.

ARGOS ID	WMO ID	DEPLOYMENT DATE	DEPLOYMENT POSITION	RECOVERY DATE
4530	44501	15 APR (106)	51-59N 52-00W	16 JUN (168)
4540	44502	15 APR (106)	49-59N 50-30W	17 JUN (169)
4558	44503	30 APR (121)	46-59N 47-19W	21 JUN (173)
4563	44504	19 MAY (140)	53-00N 52-05W	16 JUN (168)
4564	None Assigned	5 JUN (157)	52-00N 52-00W	FAILED ON DEPLOYMENT
4566	44505	1 AUG (214)	59-01N 61-26W	27 OCT (301)

BUOY DEPLOYMENT STRATEGY

A recent study (FENCO,1987), sponsored by the AES, devised strategies for the optimum deployment strategy for drifting buoys used to derive oceanic currents for iceberg drift forecasting. This study focused on Canadian domestic iceberg interests, that is, on regions where offshore oil exploration is taking place (the slope and shelf east of Newfoundland and Labrador). Although the area of Ice Patrol operations extends far to the south of this region, many of the study results apply directly to the IIP mission.

The study showed that, even for a small portion of the region (250 km x 250 km), at least 400 buoys would be required to resolve the eddy field throughout the iceberg season. Ice Patrol's operations area is many times this size. The costs associated with deploying and tracking many hundreds of buoys far exceeds the entire Ice Patrol budget. Thus, such coverage is impractical.

Ice Patrol's buoy deployment strategy focuses on the current that is the major conduit of icebergs into the North Atlantic shipping lanes, the southward-flowing off-shore branch of the Labrador Current. The goal is to monitor this current for the entire season by keeping one or two buoys in it at all times.

Several of the study's conclusions and recommendations support Ice Patrol's recent deployment strategies with the intent of gaining the most benefit from a few buoys. A fundamental conclusion of the study is to deploy buoys as far north (north of 50°N) as possible because the southward mean flow of the Labrador Current will carry the buoys into the southern areas of interest. Ice Patrol's experience has shown that this approach is reasonable with two important limitations. The first is that early in the iceberg season (March and April) the buoys should not be deployed in areas with significant concentrations of sea ice (> 3/10) so that wind-driven movement of the sea ice will not contaminate the drifter data. Second, in many cases buoys deployed from 50 - 52°N move eastward to the north of Flemish Cap, and hence do not enter the region south of Flemish Pass. Because Ice Patrol requires drift data in this area, it is frequently necessary to deploy buoys directly in the pass to ensure that the buoy will move to the south. In this case the buoys are deployed at 47°N between 46-30°W and 47-30°W.

The study recommends against releasing a buoy beside a particular iceberg because, in a period of a few days, the buoy and the iceberg are likely to be separated by distances larger than the typical eddy scales. This is a sound recommendation. Ice Patrol deploys buoys near drifting icebergs only for specific iceberg drift studies, not for operations.

Finally, the study recommends a thorough review of the Ice Patrol mean current file and the inclusion of data on the variability of the current. Ice Patrol has begun such a review and is using drift tracks collected since the beginning of the buoy program (1976) to improve the mean current data.

AIRCRAFT DEPLOYMENTS

Ice Patrol has deployed satellite-tracked buoys from HC-130's since 1979. The buoy is strapped into an air-deployment package and launched out the rear door of an HC-130 flying at an altitude of 500 feet (150 m) at 150 knots (77 m/s). The air-deployment package consists of a wooden pallet and a parachute, both of which separate from the buoy after it enters the water. The parachute riser is cut by a cable-cutter that is activated by a battery that energizes when immersed in salt water. The pallet separates when salt tablets dissolve and release straps holding the buoy to the pallet. The buoy then floats free and the drogue falls free and unfurls.

The air-deployment package failed in half (3 of 6) of the 1988 launches. The failures were similar in that the wooden pallet that holds the buoy and drogue together broke apart when it entered the HC-130's airstream. In all cases the parachute operated properly and the buoys descended to the surface at a normal speed. Two of the buoys (4563 and 4566) transmitted normally, but one (4564) failed to transmit after its deployment. It is not certain that the buoy failure was due solely to the failure of the drop package. In most cases the buoy survives and the most serious result is that the parachute remains attached to the buoy hull. When this happens the parachute can act as a near-surface drogue until it collapses and entangles with the buoy hull or drogue tether.

DATA PROCESSING

Although the raw position and temperature data are relatively noise free, all records are scanned before processing to ensure quality control. First, duplicate positions and positions with time separations of 30 minutes or less are deleted. Then, positions < 700 m from adjacent positions are deleted, unless the deletion results in a time separation of four or more hours.

The error-free position data are then fitted to a cubic spline curve to arrive at an evenly-spaced record with an interval of three hours. This process results in a slight reduction in the number of fixes per day (from 10 to 8). Next, the position records are filtered using a low-pass cosine filter with a cut-off of 1.16 x 10-5 Hz (one cycle per day). This filter removes most tidal and inertial effects. Finally, the buoy drift speeds are calculated at three-hour intervals using a two-point backward differencing scheme.

Most of the trajectory plots presented in this report are from the filtered records. Also presented for each buoy is a plot of the time history of the U (east is positive) and V (north is positive) components of velocity from the filtered records. Finally, a time history of the raw sea surface temperature data is plotted for each buoy. The dates used in all of the plots are year-dates, which are numbered sequentially starting at 1 on January 1. In the text, the year-dates are included parenthetically.

BUOY TRAJECTORIES

In the following sections each buoy trajectory is discussed separately, presented in chronological order by buoy deployment date. Only the operational buoys are discussed.

The intent of the following discussions is to summarize each buoy's performance and the data that it contributed to Ice Patrol operations. It is not intended to be an exhaustive data analysis. The buoy data from the area east of 39°W, the eastern boundary of the Ice Patrol operations area, are not presented. All of the data from the IIP drifting buoy program are archived at the IIP office in Groton, Connecticut.

Buoy 4530

Buoy 4530 (Figure B-1) was deployed at 1622Z on 15 April (106) at 51-59N, 52-00W. It provided uninterrupted data until its recovery by USCGC NORTHWIND (WAGB 282) on 16 June (168), a span of 63 days. During the first four days following 4530's deployment, the drogue sensor reported drogue detachment. It's likely that there was some type of tangle of the tether which eventually freed itself. Thereafter, the drogue sensor showed the drogue was attached for the entire drift period.

The movement of 4530 during the first twenty days after its deployment was characterized by a sluggish (<20 cm/s) southwestward drift. On 8 May (129) it started a persistent, but still slow, northeastward movement to the vicinity of the 1000 m isobath. The remainder (after 29 May, 150) of the trajectory was southward, approximately parallel to the 1000 m isobath at about 20-30 cm/s.

During its entire drift, the sea surface temperature recorded by 4530 was less than 3°C.

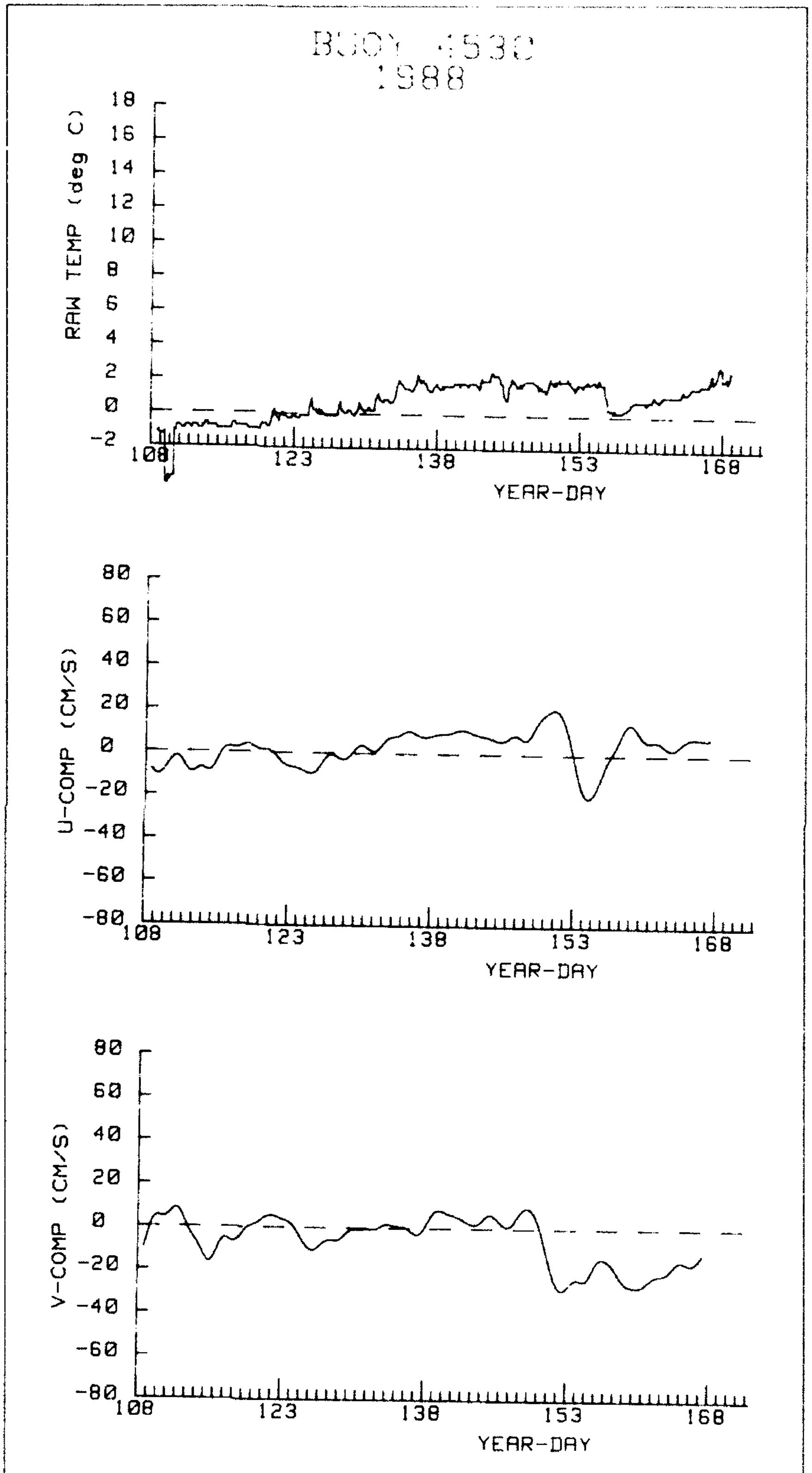

Figure B-1a. Time history of sea surface temperature, U, and V velocity components (filtered) for 4530.

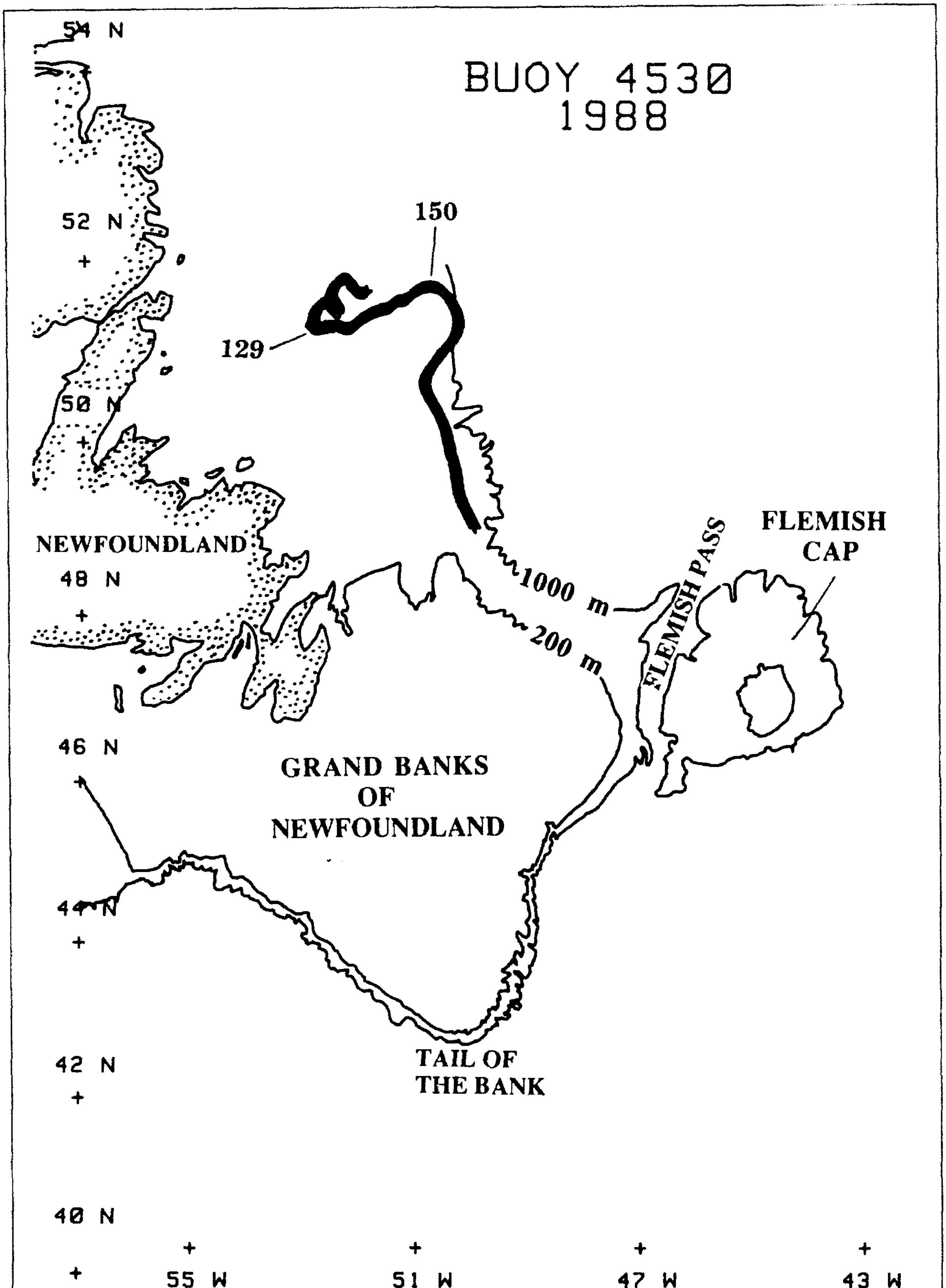

Figure B-1b. Trajectory for 4530.

Buoy 4540

Buoy 4540 (Figure B-2) was deployed at 1532Z on 15 April (106) at 49-59N, 50-30W. It was recovered by NORTHWIND 64 days later (17 June, 169). The drogue sensor data indicated that the drogue was attached during the entire drift period.

During the first 31 days of drift (106-137), 4540 moved southeastward and then eastward, approximately parallel to the 1000 m isobath. Its speed along this path varied substantially, from 2 to 40 cm/s. As shown in Figure B-2b, the period of this variability is roughly three days.

On 16 May (137), 4540 started a southward movement through Flemish Pass, again following the 1000 m isobath. Again the variability of the speed along the path was substantial (4-30 cm/s). On 31 May (152), 4540 reversed its direction and moved northward following the 1000 m isobath on the eastern side (Flemish Cap side) of the Pass. Again there were wide variations in the speed (1-22 cm/s). On 14 June (166) there was another reversal in the direction in movement, with the buoy again moving southward.

There was no evidence in the 4540's temperature to suggest involvement with any significant thermal features. The temperature increased slowly from -1°C to 6°C over the first 42 days (0.2°/day) and remained stable thereafter.

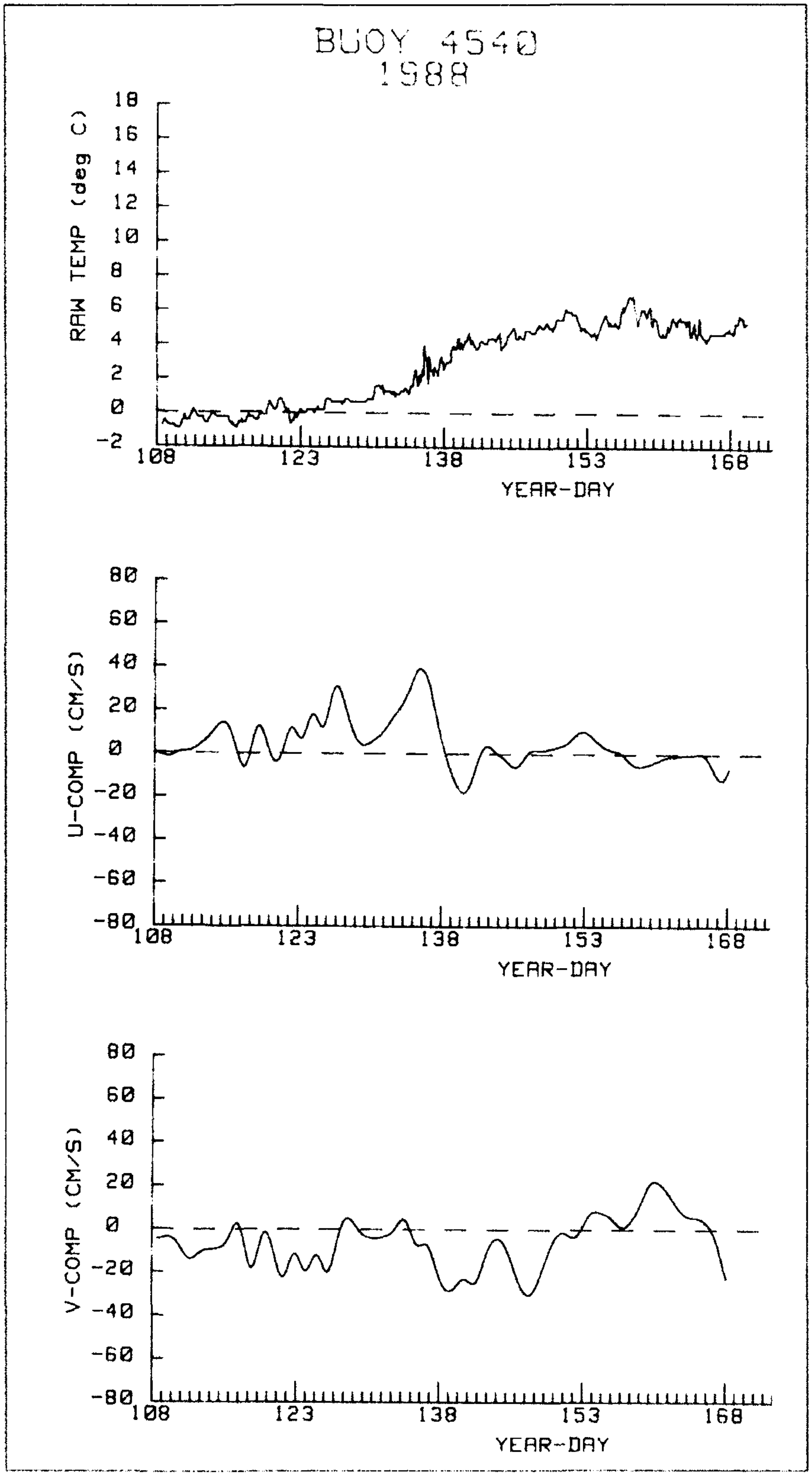

Figure B-2a. Time history of sea surface temperature, U, and V velocity components (filtered) for 4540.

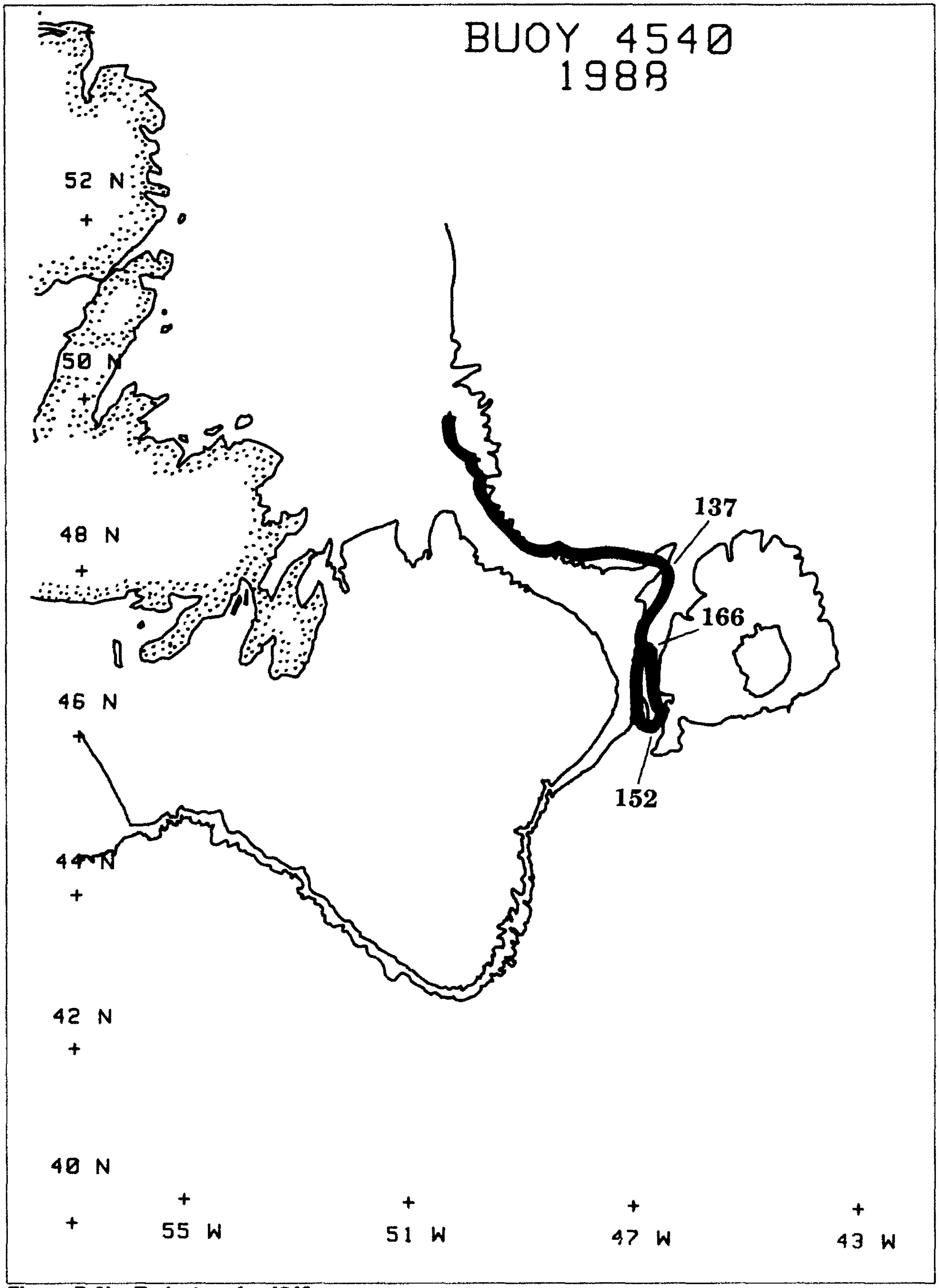

Figure B-2b. Trajectory for 4540.

Buoy 4558

Buoy 4558 (Figure B-3) was deployed at 1551Z on 30 April (121) at 46-59N, 47-19W. On 21 June (173), after 53 days of drift, it was recovered by NORTHWIND. The drogue sensor accurately reported that the drogue was attached for the entire drift period.

During the first 28 days (until 28 May, 149) following 4558's deployment, it moved persistently southward toward the Tail of the Bank following the 1000 m isobath at speeds of about 25 cm/s. Near 44-30N peak buoy speeds of 50-60 cm/s were observed over short intervals (<6 hours). Over most of this 28 day period the surface temperature increased slowly from 1 to 4°C (0.2°C/day). On 22 May (143) the temperature increased rapidly (0.2°C/hr) from 4-9°C.

On 28 May (149) 4558 turned northwestward, following the 200 m contour. On 10 June (162) it began a persistent southward, off-slope motion. The temperature which had remained in the 8-11°C range since the rapid increase on 22 May, increased from 11 to 14°C over a four day period starting on 17 June (169).

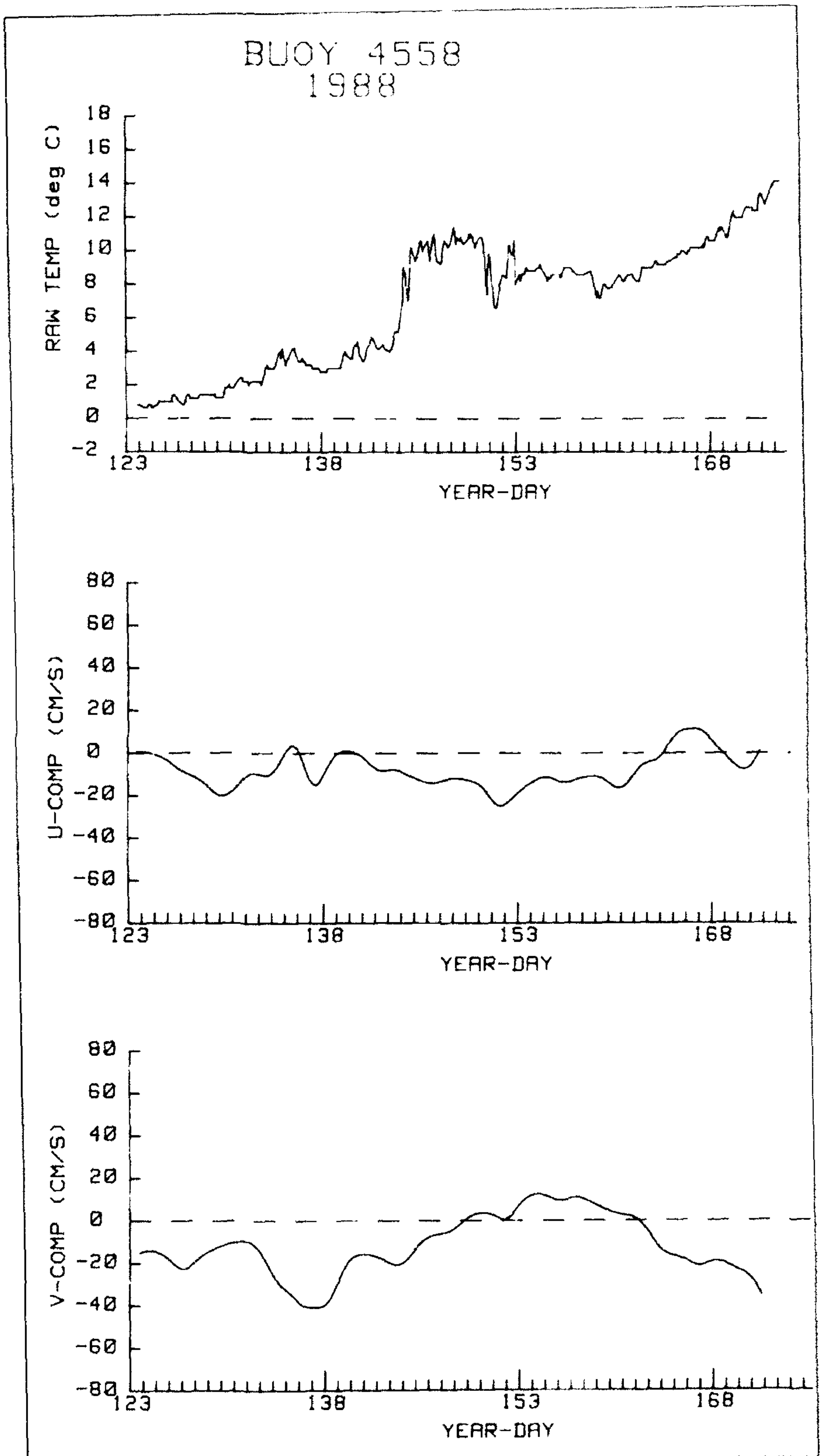

Figure B-3a. Time history of sea surface temperature, U, and V velocity components (filtered) for 4558.

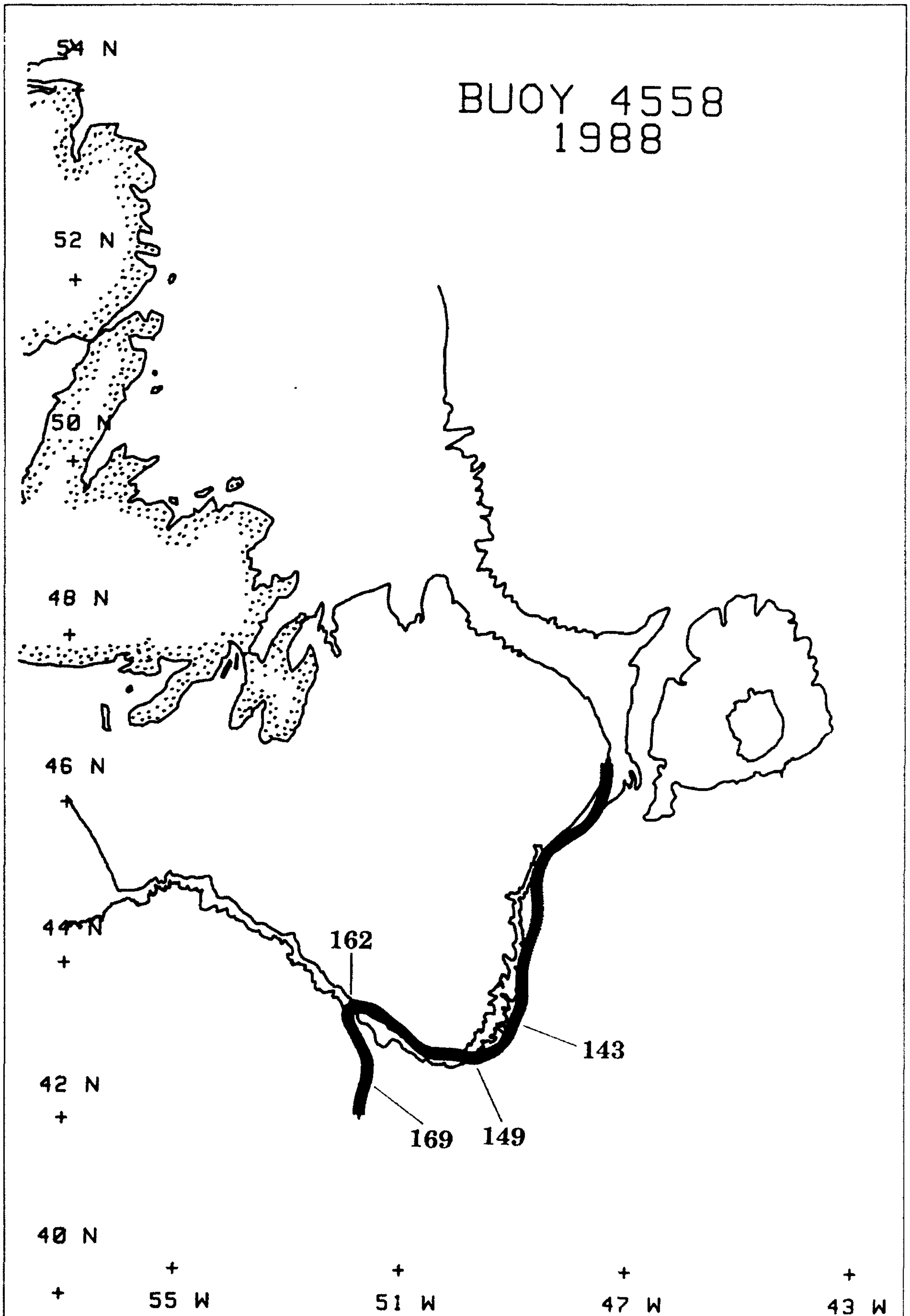

Figure B-3b. Trajectory for 4558.

Buoy 4563

Buoy 4563 (Figure B-4) was deployed at 1719Z on 19 May (140) at 53-00N, 52-05W. It was recovered by NORTHWIND on 16 June (168), 29 days after its deployment. The drogue sensor accurately reported that drogue was attached for the entire drift period.

The first eight days of 4563's drift were marked by vigorous (40-50 cm/s) southward motion along the 1000 m isobath. On 27 May (148) it moved southwestward into shallower water, whereupon four days later, its motion slowed substantially (<20 cm/s). The remainder of its drift was characterized by sluggish movement in the vicinity of 50N, 51-30W.

The temperature record from 4563 is unremarkable, with a slow increase in temperature from 0-3°C over the 29 day drift (0.1°C/day).

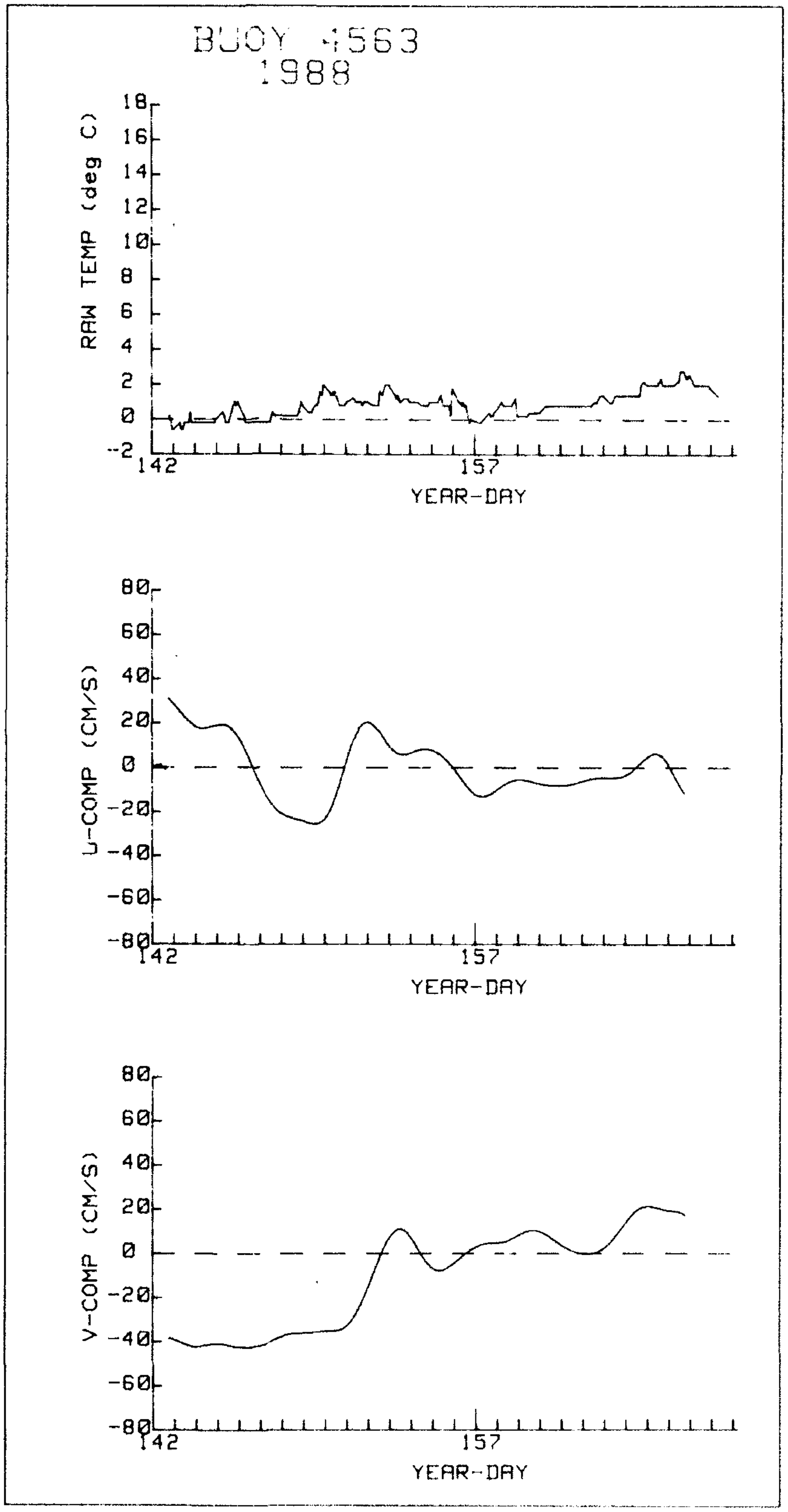

Figure B-4a. Time history of sea surface temperture, U, and V velocity components (filtered) for 4563.

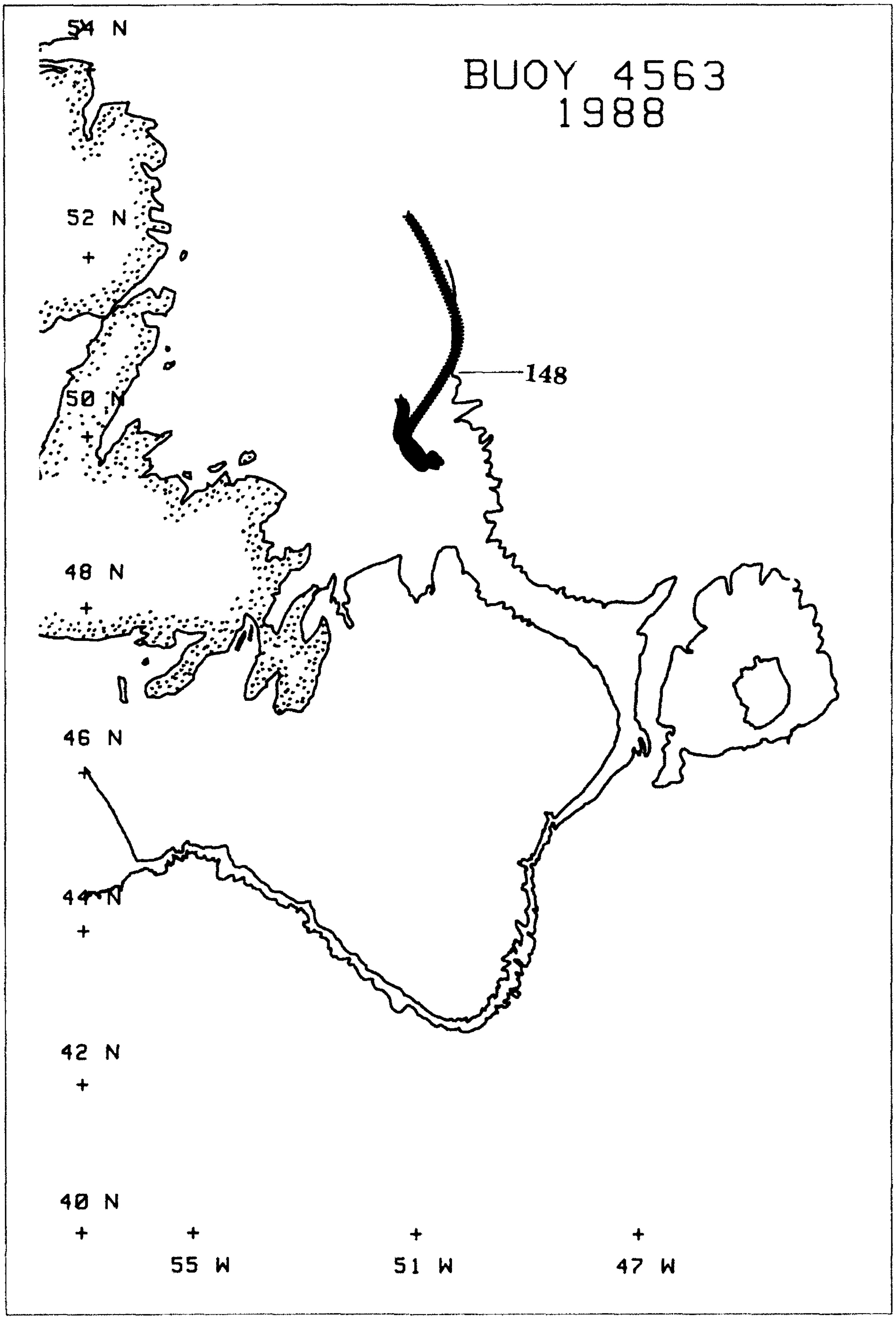

Figure B-4b. Trajectory for 4563.

Buoy 4566

Buoy 4566 (Figure B-5) was deployed at 1351Z on 1 August (214) at 59-01N, 61-27W. After 89 days of drift, 4566 was recovered by SIR JOHN FRANKLIN on 27 October (301). The drogue sensor indicated several short periods when the drogue appeared to be detached. These periods occurred when the buoy was in relatively shallow water (<100 m). It is likely that the drogue was resting on the bottom during these periods. Most of the drogue sensor data accurately showed the drogue was attached for the entire drift period.

Buoy 4566 was deployed at the same time and location as a mini-drifter that was provided by AES (Buoy 3435). The intent of the concurrent deployment was to compare the performance and drift of the two buoy types. Unfortunately, the mini-drifter failed after about twelve hours in the water.

The movement of 4566 during its 88 day drift was generally south-eastward. It is complicated for two reasons. The first is the complex flow along the Labrador Coast due to the convoluted bottom topography. Second, the standard buoy configuration has a 50 m drogue tether, which means that the bottom of the drogue extends to a depth of over 60 m. Several of the banks along the coast have shallower depths. In particular, during the period from 26 August to 6 September (239-250) 4566 was grounded on a pinnacle east of Nain, Labrador. There is no clear evidence for further grounding, but there is one short period of sluggish motion when 4566 was on Hamilton Bank (12 October 286).

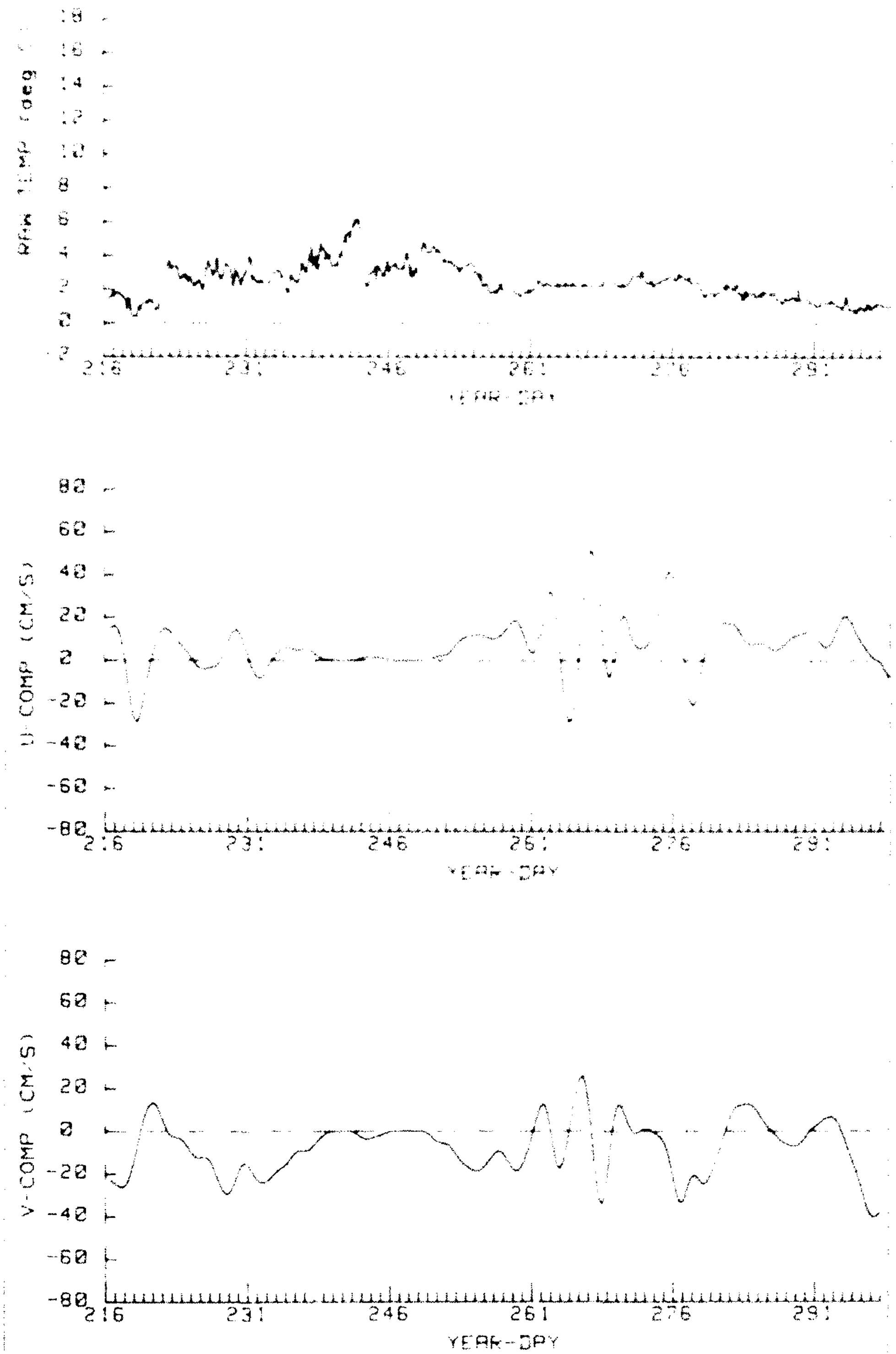

Figure B-5a. Time history of sea surface temperature, U, and V velocity components (filtered) for 4566.

The most vigorous motion during 4566's drift came during a sixteen day period (17 September to 20 October, 261-276) when it was moving across Makkovik and Harrision Banks. At times 4566's speed exceeded 50 cm/s.

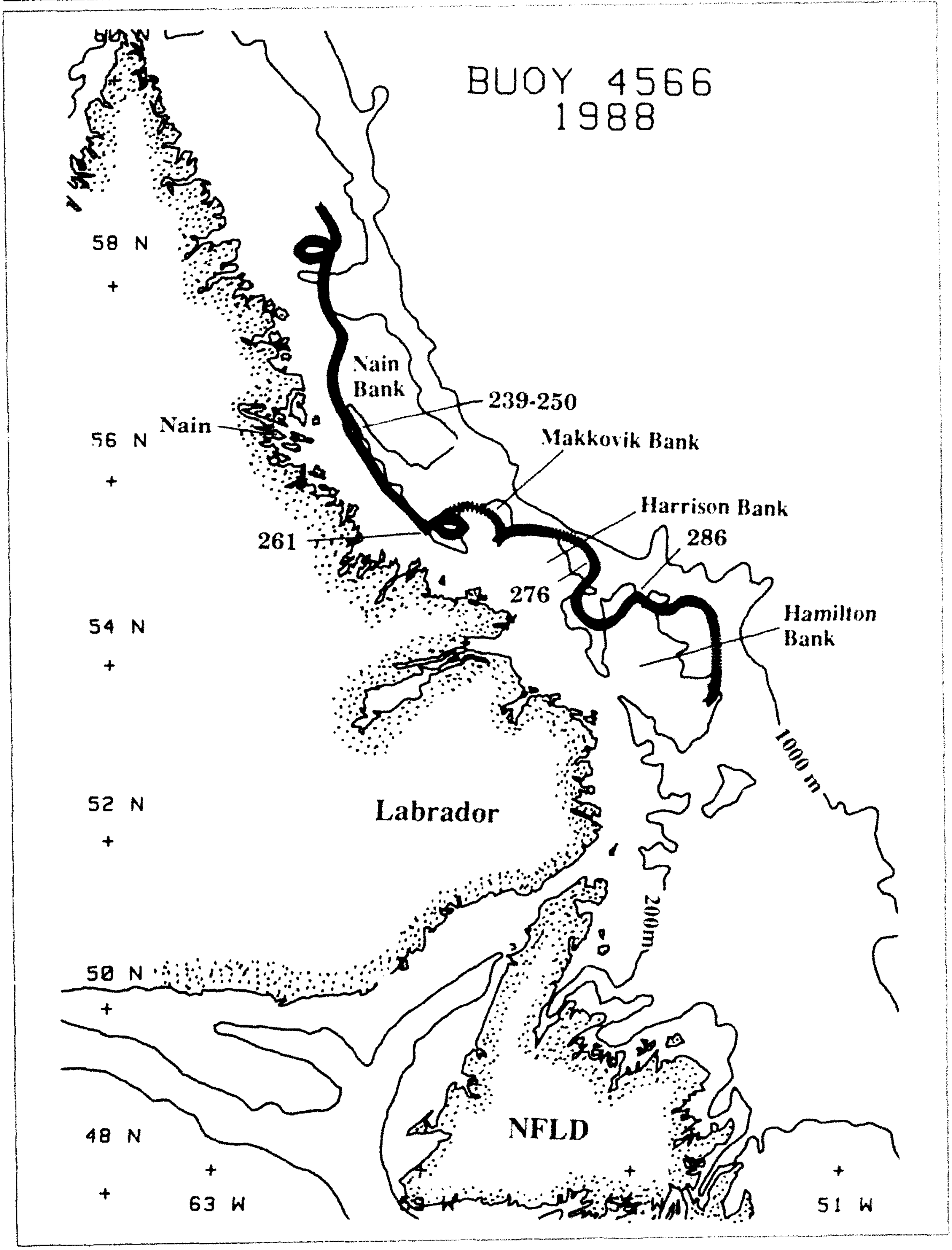

Figure B-5b. Trajectory for 4566.

BUOY RECOVERIES

In 1988 Ice Patrol had the rare opportunity to recover five of the six buoys deployed during the season. Buoy 4564, which failed completely upon splash-down, was the only operational buoy not recovered. Four buoys (4530, 4540, 4558, and 4563) were recovered by USCGC NORTHWIND, which was conducting an Ice Patrol Research Cruise (IIP 88-1) that carried the vessel near the buoys. The fifth (4566) was recovered by the Canadian Coast Guard icebreaker CCGS SIR JOHN FRANKLIN.

Recovering the buoys serves three purposes. First, it permits the reuse of the buoys in the next season, saving $6-8,000 per recovered buoy. Second, it permits Ice Patrol to determine whether the drogue remained attached during the entire drift period. A detached drogue results in the buoy moving with the near-surface currents rather than the currents at about 50 m, which is more appropriate for iceberg drift predictions. Finally, it permits Ice Patrol to evaluate the effectiveness of the air-deployment package, e.g., whether or not the parachute detached, whether the drogue deployed properly. From these findings, design improvements can be made.

Table B-2 summarizes the buoy recoveries.

All five recovered buoys had the drogues attached when they were recovered. Two of the buoys (4563 and 4530) also had their parachutes attached. In both cases, the parachute cutters were still in their place in the collar, but there was damage to the power cords, suggesting that in both cases the air-deployment package failed. The parachute was entangled in the first few meters of the drogue tether, so the parachute was not acting as a near-surface drogue. A review of the Ice Patrol Reconnaissance Detachment (ICERECDET) trip reports showed that 4563's pallet broke apart during the deployment, and the parachute did not separate from the buoy when it entered the water. Although the deployment of 4530 appeared to be normal, the ICERECDET could not confirm that the parachute separated from the buoy despite three fly-bys after the deployment.

All of the recovered hulls were in excellent condition, with no bio-fouling. All of the drogues exhibited some minor damage, such as short tears or abrasions. The antenna housing of buoy 4563 had a hairline crack of unknown origin near its base, but the buoy's performance was unaffected.

Table B-2. Summary of Buoy Recoveries.

ID	RECOVERY DATE	LOCATION	PARACHUTE ATTACHED	DROGUE ATTACHED
4563	16 JUN (168)	50-30.5N, 51-40W	YES	YES
4530	16 JUN (168)	48-59.4N, 49-47.4W	YES	YES
4540	17 JUN (169)	46-42.4N, 47-02.3W	NO	YES
4558	21 JUN (173)	41-32.8N, 51-27.8W	NO	YES
4566	27 OCT (301)	53-40.8N, 52-22.6W	NO	YES

A review of the drogue sensor data provided by the five recovered buoys shows that the presence of the drogue was reliably reported in all cases. Two of the buoys (4530 and 4566) had short periods (< 4 days) during which the drogue sensor indicated detachment. In the case of 4566 it occurred when the buoy entered a shallow area and it is likely that the drogue was dragging on the bottom. In the case of 4530 it occurred during the first four days after its launch. This suggests tangle of the tether which eventually broke free. After the buoy and drogues were recovered all of the drogue sensors properly recorded drogue detachment.

MINI-DRIFTING BUOYS

Since 1986, the International Ice Patrol has been cooperating with the U. S. Naval Oceanographic Research and Development Activity (NORDA) in field testing small (~ 1 m long and 20-30 kg) and low cost ($2-3,000) drifting buoys. These mini-drifters have a design life of 3-4 months and come in a variety of configurations. There are several reasons why they might be more appropriate for use in the Ice Patrol buoy program than the currently-used standard configuration. The smaller buoys cost less than half as much as the standard buoys, which would permit more than doubling the number of buoys deployed each season for the same cost. Their small size makes storing, transporting, and deploying the buoys easier. Finally, their design life is well-matched to the average period that a drifter remains in the Ice Patrol operations area (2-3 months). The current configuration transmits for about a year, while the buoy typically remains in the Ice Patrol operation area and the drogue remains attached for about a third of that time.

Before integrating the mini-drifters into the Ice Patrol program, the issues of reliability, accuracy, and drift characteristics need to be considered. Anderson (1987) described the details of a 1986 field test, which was conducted entirely in the relatively calm and warm waters of the Gulf of Mexico. Thayer et. al. (1988) and Pickett (1989) describe the 1988 field tests, which were conducted in both the Gulf of Mexico and the rougher and colder waters of the North Atlantic. The goals of these two tests were essentially the same: first, to determine if the buoys would survive air deployment over a wide range of altitude and speeds and, second, to determine if the buoy lifetime and number of ARGOS fixes per day was consistent with the performance of the standard buoys.

The 1988 field tests showed that the buoys survived the air drops well, but that the buoy life was far short of the 3 month design life. All of the mini-drifters used in the 1988 tests were Compact Meteorological and Oceanographic Drifters (CMOD), which are manufactured by METOCEAN of Halifax, Nova Scotia. The drogue consists of the cylindrical outer case of the drifter (approximately 12 cm by 70 cm) tethered at 100 m. The buoys are equipped with a barometer, air and sea surface temperature sensors. There is no drogue sensor.

The 1988 tests showed that the CMOD's survived an average of 34 days in the Gulf of Mexico and 17 days in the North Atlantic. Of the five deployed by Ice Patrol aircraft, two were deployed in the Ice Patrol operations area (1388 and 1387). Buoy 1388 failed upon deployment and 1387 provided data for fifteen days. Two CMOD's (1386 and 1389) were deployed in the North Atlantic by Ice Patrol aircraft enroute between the United States and Newfoundland. Buoy 1386 transmitted data for 22 days after its deployment and 1389 for thirteen days. The fifth CMOD (3435), deployed by Ice Patrol for AES, was launched with a standard buoy (4566). Buoy 3435 failed after twelve hours of drift and its track is of little value. The data from the one CMOD (1387) that did provide a significant trajectory in the IIP operations area are described below.

Buoy 1387

Buoy 1387 was deployed from an HC-130 at 47-01.0N, 47-10.8W at 29 March (89) at 1730Z. It abruptly failed on 12 April (103). During its 15 day drift, it transmitted seven to eight fixes each day, which is similar to the number received from the standard configuration. The accuracy of the fixes provided by 1387 was essentially the same as those received from the large buoys. This determination was made by examining the quality index of each fix, a value provided in the data stream from Service ARGOS. Most of the fixes fell into category two, which indicates the standard ARGOS accuracy (one standard deviation) of 350 m.

The wind conditions during the drift period were light to moderate (3-12 m/s), mostly from the north and northeast. As a result, it was not a severe test of the buoy from the standpoint of wind and wave conditions.

The trajectory plot (Figure B-6a) presents the raw position data. Because of the short record, the position data were not filtered. Filling the filter would have used too much data to make its use practical. The U and V components presented in Figure B-6b are 3-hourly interpolated values.

During its fifteen day drift, buoy 1387 moved persistently southwestward mostly at speeds in the 20-40 cm/s range. Several speeds in excess of 60 cm/s were recorded early in the drift period (31 Mar, 91). The trajectory crosses the 1000 m contour near 46°N, which is further to the north than usual. More frequently, buoys deployed in Flemish Pass

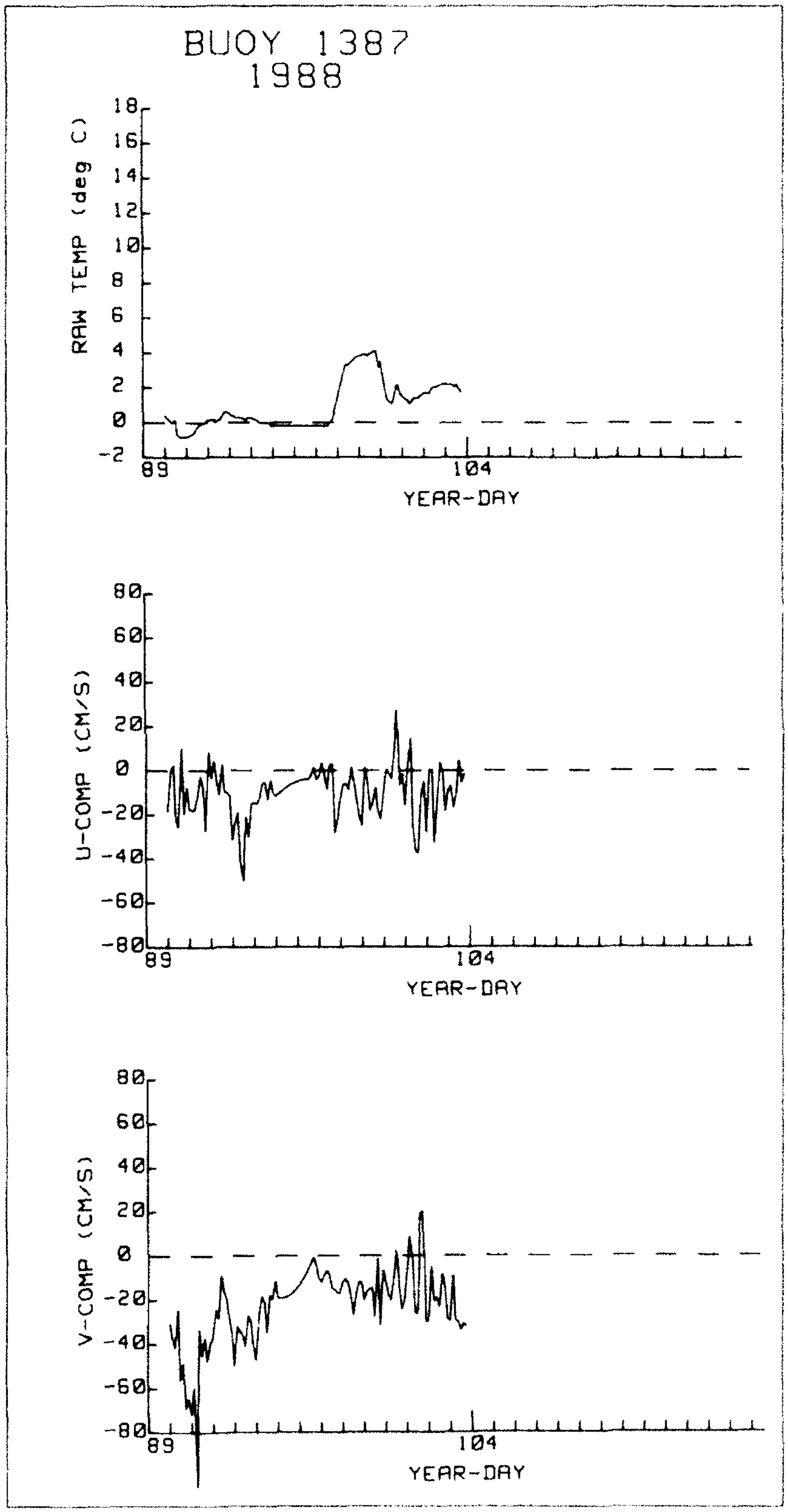

Figure B-6a. Time history of sea surface temperature, U, and V velocity components (interpolated 3 hr) for 1387.

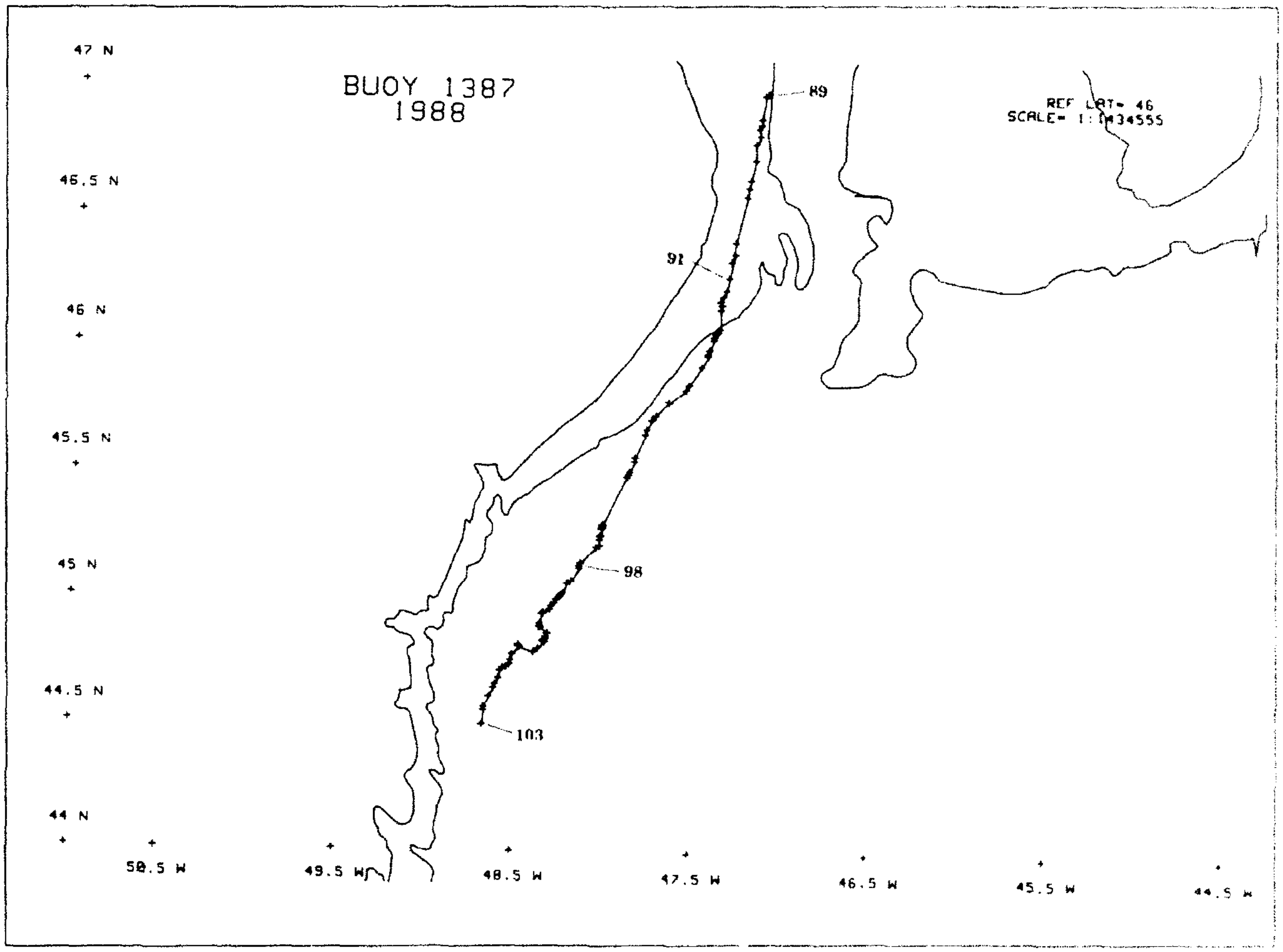

Figure B-6b. Trajectory for CMOD 1387 (raw data).

follow the 200 to 1000 m contours quite closely in the region north of 44°N. However, not much can be said about the drift characteristics of the CMOD based on one short trajectory. In addition, the CMOD drogue is at 100 m while that of the standard buoy is centered at 58 m. As a result, a direct comparison is not possible.

Buoy 1387's temperature record shows an abrupt temperature increase (0-4°C) on 7 April (98). There was no concurrent change in the buoy's motion.

SUMMARY AND CONCLUSIONS

The data return from the 1988 buoys was excellent. The average drift period for the five operational buoys was 59 days. None of the buoys moved east of 39W, the eastern boundary of the Ice Patrol operations area.

Recovery of the five buoys showed that the drogues remained attached and that the drogue sensors worked well. The recoveries also showed that if the parachute remains attached to the buoy, it entangles with the drogue tether and does not contaminate the drift data seriously. For example, buoy 4563 had been in the water for 29 days when it was recovered. The parachute, which had not cut free, was collapsed and inextricably tangled in the tether. Although the buoy recoveries save some money, the more important benefit was the ability to examine the buoys after substantial drift periods (29 to 88 days).

It is not likely that buoy recoveries will become routine events. The cost of ship time far exceeds any savings that result from reuse of the buoys. However, when a ship-of-opportunity is available, every effort should be made to recover and document the condition of buoys.

The failure of three air-deployment packages was cause for concern. The manufacturer has redesigned the package for use in the 1989 season.

The mini-drifter test results continue to show promise, but not all of the issues have been resolved. The reliability and life expectancy of the buoys must be increased substantially before the issue of drift characteristics is considered. Only one buoy type from one company has been tested. Testing should be expanded to include others.

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Appendix C
Upgrade of Environmental Inputs to Iceberg Forecasting Models

LCDR Walter E. Hanson, Jr.

INTRODUCTION

The International Ice Patrol (IIP) uses two numerical models in its operations: an iceberg drift model and a model to estimate deterioration. The currently-used drift model (Mountain, 1980) balances iceberg acceleration, air and water drag, the coriolis acceleration and a sea-surface slope term. The iceberg deterioration model (White, et al 1980 and Anderson, 1983) sums the effects of calving from wave erosion, heat convection from the relative movement of the iceberg through the water, buoyant heat convection, and solar radiation.

Both of IIP's models require substantial input data. The drift model requires marine surface wind and oceanic current data for its twice-daily drift predictions. The deterioration model, which is run once each day, requires sea surface temperature (SST), wave height, and wave period data. Most of these data requirements (all except oceanic current data) are filled by the U. S. Navy's Fleet Numerical Oceanography Center (FLENUMOCEANCEN), located in Monterey, California. All of the data are transferred to IIP over telephone lines using the Navy/ NOAA Ocean Data Distribution System (NNODDS).

Recently, close cooperation between FLENUMOCEANCEN and IIP oceanographers has resulted in significant improvements in the inputs to IIP's models. The efforts are occurring in two areas. First, with USN help, IIP is making use of the latest in the rapidly-improving suite of FLENUMOCEANCEN data products. Second, IIP has been working to increase its oceanographic data collection in its operating area (40°N - 52°N, 39°W - 57°W), recognizing that if FLENUMOCEANCEN receives more and better data, then products will improve. The following two sections briefly describe some of the recent activities in each area.

ENVIRONMENTAL PRODUCTS

Wind

IIP's iceberg drift model requires a 96-hour wind history for its air drag calculations. To satisfy this requirement FLENUMOCEANCEN produces a 12-hour averaged wind field for IIP from its Navy Operational Global Atmospheric Prediction System (NOGAPS) (NEPM, 1986) marine surface wind. It is a thermally-stable wind at 19.5 m above the sea surface.

NOGAPS calculates wind vectors on a geographically referenced projection with a grid spacing of approximately 250 km. FLENUNOCEANCEN lineraly-interpolates the wind to approximately 140 km grid-spacing for use in the IIP model. The data are provided twice a day (0000Z and 1200Z), with forecasts for each 12 hours out to 36 hours.

Beginning in mid-March 1989, FLENUMOCEANCEN will provide IIP with marine surface winds interpolated for 10 m above the sea surface (NOGAPS 3.1). Since marine wind speeds vary logarithmically with height above the sea surface, and because wind forcing plays an important role in estimating the drift of small icebergs, particularly growlers, this 10 m wind should improve IIP iceberg drift predictions.

The linear interpolation used by FLENUMOCEANCEN to produce ICEWINDS at 140 km grid-spacing does not adequately represent mesoscale features, such as meteorological waves. By summer 1989, FLENUMOCEANCEN plans to spectrally interpolate the winds (NOGAPS 3.2). This will better describe wind curvature along mesoscale features and should improve the direction of the wind forcing component. The grid-spacing of this product will be 155 km, thus no further interpretation will be required to use the data in the IIP drift model.

Sea Surface Temperature

Sea surface temperature is the most important input to IIP's iceberg deterioration model. Currently, the SST data used in the model are from FLENUMOCEANCEN's Expanded Ocean Thermal Structure (EOTS) analysis (NEPM, 1986). The temperatures are for 1 m below the sea surface and are determined on a relatively coarse 320 km gird. As with the wind data, the temperatures are interpolated to a 140 km grid for use in the IIP model. The temperature field is valid for 0000Z. Using the temperature at the predicted 0000Z iceberg position, IIP models iceberg deterioration over the previous 24 hours.

The major problem with the coarsely-spaced EOTS temperature data was that it could not represent the spatial variability in the vicinity of the Grand Banks, where the cold (3°C), narrow (50 km wide) iceberg-carrying Labrador Current converges with the warm (12°C) North Atlantic Current. FLENUMOCEANCEN worked with IIP to improve the database and now provides a composite SST field, which has a 35 km grid-spacing. FLENUMOCEANCEN extracts data from the global EOTS, a regional Gulf Stream EOTS, and the Labrador Sea EOTS products. This FLENUMOCEANCEN effort greatly improved the SST input to the IIP deterioration model. The new product, when "bogused", agrees well with observations and with the SST analyses produced by Canadian Forces METOC Halifax. (Bogusing is the means by which discontinuities, in this case oceanid fronts, precludes numerical models from blending dissimilar data sets (Hawkins et al, 1986).)

Wave Height and Period

Wave height and period input is produced by the FLENUMOCEANCEN Global Spectral Ocean Wave Model (GSOWM) (Clancy et al, 1986). The GSOWM field is produced on a geographically-referenced projection with a grid-spacing of approximately 235 km. FLENUMOCEANCEN linearly-interpolated it to approximately 140 km grid-spacing.

FLENUMOCEANCEN has provided twice daily now casts (valid for 0000Z and 1200Z) of wave height, period and direction since 1983. The direction parameter is not used by IIP since the deterioration model assumes an omnidirectional wave field. Prior to June 1988, significant wave height and primary wave period were provided. In June 1989 IIP began receiving concurrently significant wave height, primary wave period, sea height, and sea period. Sea height and period are derived from a sea/swell separation algorithm implemented in GSOWM (Clancy, 1987).

In August 1988 IIP substituted sea height and sea period for significant wave height and primary wave period respectively.

DATA COLLECTION

This year, all of the environmental products have also been improved by U. S. Navy support of new IIP data collection efforts. This provider/user cooperation significantly improved Labrador Sea temperature products and provided important barometric pressure information in normally data-sparse areas of the NW Atlantic. Much of the IIP operating area is often obscured by clouds and fog, which limits the use of satellite-derived temperature data. The ice conditions, prevalent through most of the year, also limit shipping, thus synoptic weather reports, in the northern part of the IIP region.

IIP, with technical and logistic support from the Naval Oceanographic Office, developed a portable Air-droppable eXpendable BathyThermograph (AXBT) system (Alfultis, 1988), which accompanied nearly all HC-130 iceberg reconnaissance flights. AXBTs were dropped near oceanic fronts and a Motorola AN/APS-135 side-looking airborne radar mapped sea surface roughness. Based on IIP procedures derived from three years of research (Thayer et al, 1988), the radar imagery was used to infer the presence of oceanic fronts. JJXX messages were sent to both FLENUMOCEANCEN and the U. S. Navy Eastern Oceanography Center (NAVEASTOCEANCEN), located in Norfolk, Virginia; the radar interpretation was telecopied to NAVEASTOCEANCEN.

NAVEASTOCEANCEN used all of these data to help bogus the Labrador Sea EOTS. The highly selective data collection strategy improved EOTS representation of the Labrador Current/North Atlantic Current confluence.

IIP encouraged NAVEASTOCEANCEN and FLENUMOCEANCEN to take more advantage of IIP's drifting buoy program. IIP annually deploys 6 to 12 TIROS Oceanographic Drifters (which only measure SST) in the Labrador Current. These drifters remain in the IIP region for up to 3 months before they are entrained in the North Atlantic Current. IIP deploys them during iceberg reconnaissance flights, monitors their performance, and ensures that they are on the Global Telecommunications System for real-time data relay to FLENUMOCEANCEN. In 1988 IIP began providing drift histories to NAVEASTOCEANCEN so it could better visualize North Atlantic Current meanders and eddies. The U. S. Navy has funded the incremental cost to have barometric sensors on some IIP buoys.

EFFECT ON NEW INPUTS ON ICEBERG MELT ESTIMATES

The replacement of existing temperature and wave inputs with ones that better represented the environment were expected to affect iceberg deterioration estimates. However, from the 1987 IIP iceberg study (Hanson, 1987), IIP realized that the deterioration estimates, derived from these inputs, had to also be evaluated, before assuming that the modelled melt better represented actual melt. If the modelled melt derived from the new inputs were better, IIP would also have to redefine when icebergs could be deleted for reason of complete melt.

During June and July 1988, IIP examined the predicted melt histories of all icebergs which had been sighted on or after 3 June 1988. This date corresponded with the start of the new sea height and sea period inputs from FLENUMOCEANCEN. Concurrent deterioration estimates were generated for each iceberg by running in parallel two versions of the operational deterioration model. Both versions used the finer gridded temperature input; however, one version (V1) used significant wave height and primary wave period data, while the other (V2) used sea height and sea period. IIP used version V1 to predict all its operational iceberg deterioration estimates for the 1988 ice season.

Versions V1 and V2 were compared with regard to the "percent of melt" when icebergs were deleted from the database. Reasons to delete icebergs were based on: a thorough aerial reconnaissance of an area in which an iceberg is expected to have drifted, and no iceberg is sighted; or when icebergs exceed 175% of predicted melt, or 200% of predicted melt for those icebergs which set the "limits of all known ice". IIP studied a sample of 231 non-tabular icebergs: 71 small (assumed to be 60 m long); 102 medium (102 m long); and 58 large (213 m long). The maximum waterline length for a reported size is always assumed by the deterioration model when an iceberg is first sighted. This waterline is deteriorated over time until a new size is reported, which resets the waterline to the maximum length for that size category.

Figure C-1 shows the scatter diagrams for each iceberg size category. For nearly 90% of the sample, the V2 melt rate was equal to or slower (better) than the V1 rate. A linear regression analysis appeared useful in describing the potential improvement in modelling total melt for the large and medium-sized icebergs; the linear correlations for these size categories were high; 0.97 and 0.86 respectively. The low (0.55) correlation for the small size icebergs made linear regression a less reliable indicator for that category. The new environmental inputs appear to reduce modelling error between 10% (for large icebergs) and 35% (for medium and small icebergs). This comparison reflects only the improvements associated with using sea height and sea period. Although not measured, similar improvement in substituting the fine for the coarse resolution temperature data was expected.

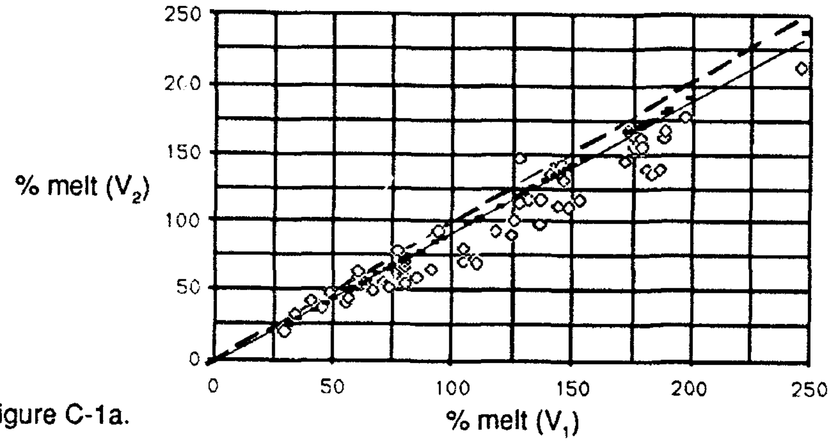

Figure C-1a.

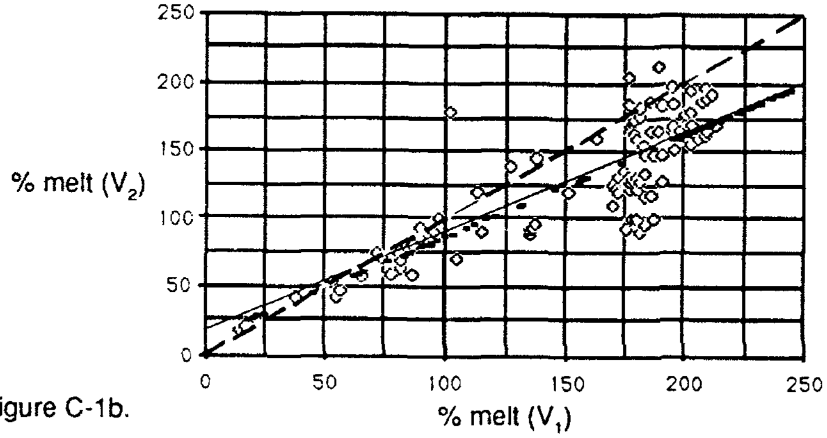

Figure C-1b.

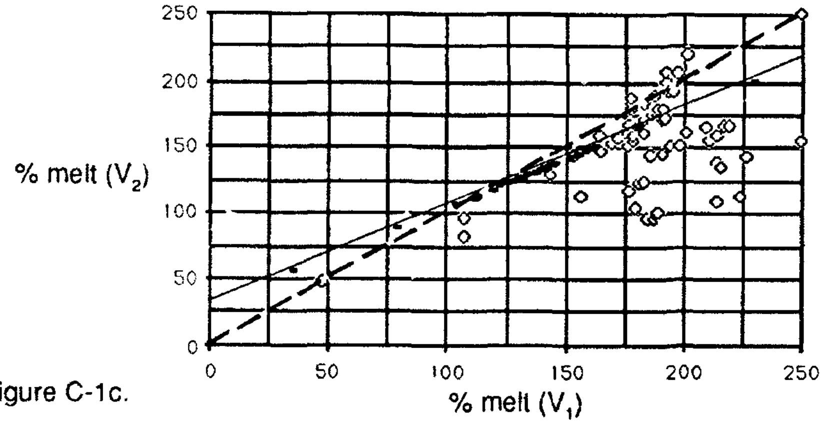

Figure C-1c.

Figure C-1. Comparative Effects of FLENUMOCEANCEN GSOWM Products on IIP Iceberg Deletion Criteria. These scatter diagrams show the "percent of melt" at the time a random series of icebergs of like size were deleted from the IIP database. The abscissa represents the "percent of melt" calculated using significant wave height and primary wave period as inputs to the IIP deterioration model. The ordinate represents the "percent of melt" calculated using sea height and sea period as inputs. The dashed line represents a 1:1 relationship. The solid line is the linear regression fit. The observation period is June/July 1988. Figure C-1a depicts the melt comparison for 58 large (213m long) icebergsl; Figure C-1b is for 102 medium (102m long) icebergs; and Figure C-1c is for 71 small (60m long) icebergs. The large concentration of data points in Figures C-1b and C-1c in the right hand portion of the graph is due to the large number of small and medium icebergs that were deleted after exceeding 175 percent of predicted melt.

In 1989, IIP intends to make two procedural changes to refine its ability to predict iceberg deterioration. The deterioration model will reset the iceberg size to the maximum waterline length for the reported size every time the iceberg is sighted. This will be a more conservative method in handling the ever-increasing quantity of iceberg data. Secondly, IIP will reduce the percent melt at which icebergs can be deleted from the database. For all icebergs, except those setting the "limits of all known ice", 125% will be the deletion criteria; for limit-setting icebergs 150%. These new deletion criteria were based on several interdependent factors: the improved estimate of iceberg deterioration provided by the new environmental inputs; the more conservative method in handling iceberg resights; and the planned improvements in iceberg drift predictions.

SUMMARY

IIP took a proactive approach to better the predictive skill of its iceberg drift and deterioration models in 1988. By concentrating on improvements to the environmental inputs, IIP reduced errors in its deterioration predictions. As an informed FLENUMOCEANCEN user, IIP was able to recognize ways in which it could enhance the quality of its environmental inputs by expanding its remote oceanographic data collection capabilities. Because technological advances have facilitated rapid advances in environmental modelling, IIP expects that the next significant improvements to its input will occur by 1993.

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Appendix D

Use of Air-deployed Expendable Bathythermographs during the 1988 IIP Season

Lt M. A. Alfultis, USCG

Introduction

The International Ice Patrol's (IIP) primary mission is to determine the southern, southeastern, and southwestern limits of all known ice in the vicinity of the Grand Banks of Newfoundland. This service is provided to transatlantic shipping by the U.S. Coast Guard, as required by international treaty and U.S. law, in response to the tragic sinking of the RMS TITANIC. The IIP uses U.S. Coast Guard HC-130 and HU-25 aircraft operating out of Newfoundland every other week to provide iceberg reconnaissance.

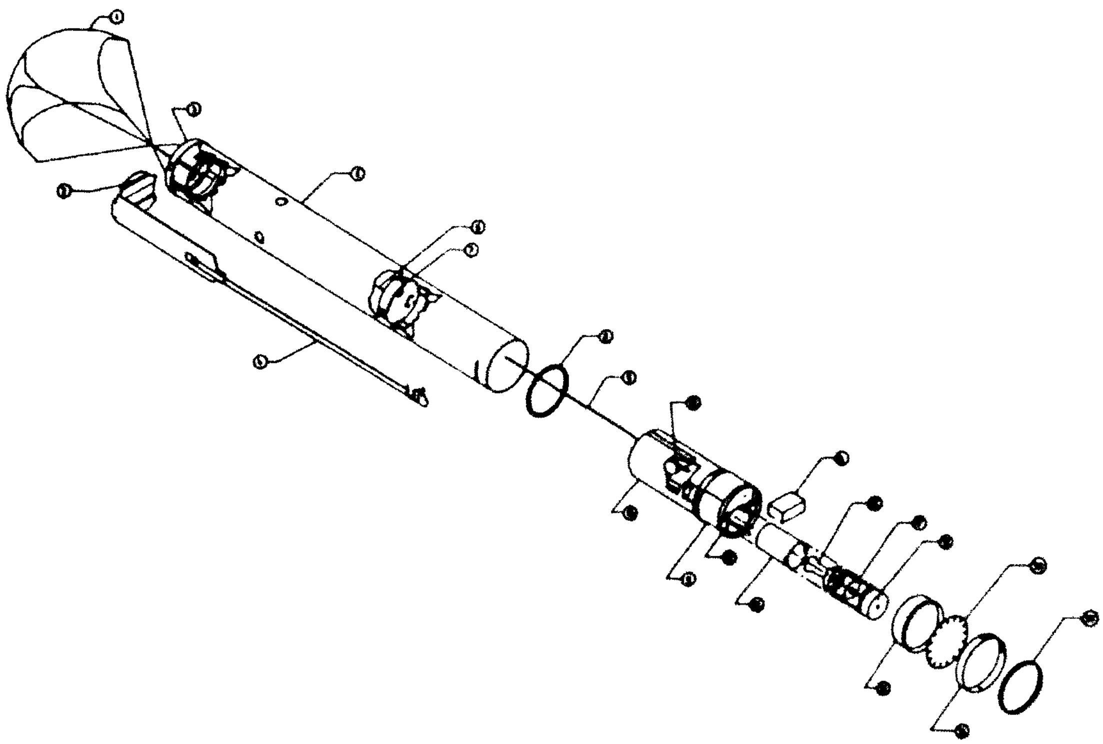
In addition to the aerial iceberg reconnaissance, IIP uses a computer model to predict iceberg drift and deterioration in support of its primary mission. Ocean temperatures are an important parameter to the iceberg deterioration computer program, and are an indication of water mass boundaries from which flow can be inferred. However, there is only a limited amount of temperature data collected in IIP's operating area. IIP sought a system to gather ocean temperature data from Coast Guard aircraft which would require no extensive airframe modifications, was portable, inexpensive, and easy to operate.

The use of Air-deployed eXpendable BathyThermograph (AXBT) probes to collect ocean temperature data from aircraft is well established in the U.S. Navy. The U.S. Navy equips dedicated aircraft (P-3's and LAMPS Helicopters) for AXBT operations. The U.S. Coast Guard aircraft, however, have several missions to support which makes this approach unsuitable. Since the Coast Guard aircraft are multimission, the AXBT system must be portable, so that any available aircraft could be used. The AXBT system would have to be inexpensive to procure, operate, and maintain. Because of these factors, IIP tested and procured an AXBT system using commercially available components. This paper summarizes the results of IIP's evaluation and operational use of this AXBT system.

Description of AXBT System

The AXBT system consists of the AN/SSQ-36 AXBT, which is deployed from the aircraft, and the receiving/recording equipment and Sippican MK-9 Data Acquisition System on the aircraft. The AN/SSQ-36 AXBT has been used for many years by the U. S. Navy for collecting subsurface temperature data from both fixed wing aircraft and helicopters. It consists of a standard sonobuoy size cannister (12 cm in diameter, 91 cm long), a parachute, a 1-watt VHF transmitter, a monopole antenna, signal conditioning electronics, a seawater battery, and temperature measuring probe (Figure D-1). Two types of AXBT's are available: the standard AN/SSQ-36 AXBT with a probe depth of 300 meters and the "deep" AXBT's with a depth of 760 meters. The performance of the AXBT is documented in Boyd (1987), and Bane and Session (1984).

After deployment from the aircraft (Figure D-2), a wind flap separates from the AXBT cannister, pulling out a parachute which stabilizes the AXBT and ensures it enters the water correctly. Once in the water, the package containing the transmitter, antenna, electronics, battery, and temperature probe separates from the outer cannister. A dead-air space in this package provides flotation to bring it back to the surface. The sea water battery activates, the transmitter turns on, and an unmodulated RF signal is transmitted to the aircraft on one of three possible VHF carrier frequencies: 170.5, 172.0, or 173.5 MHz. Thirty to forty seconds later, the temperature probe is released.



1. Parachute
2. Windflap
3. Decelerator Housing
4. Windflap Retaining Strip
5. Buoy Housing
6. Tipover Foam
7. Bulkhead
8. Shock Pad
9. Antenna
10. Float Housing
11. Float Base
12. Probe Release Cable
13. Transmitter Board
14. Seawater Battery
15. Probe Afterbody
16. Probe Spool
17. Probe Electronics
18. Probe Nose
19. Deployment Weight
20. Release Plate
21. Nose Clamp Ring
22. Support Ring

Figure D-1. Sippican AN/SSQ-36 AXBT.

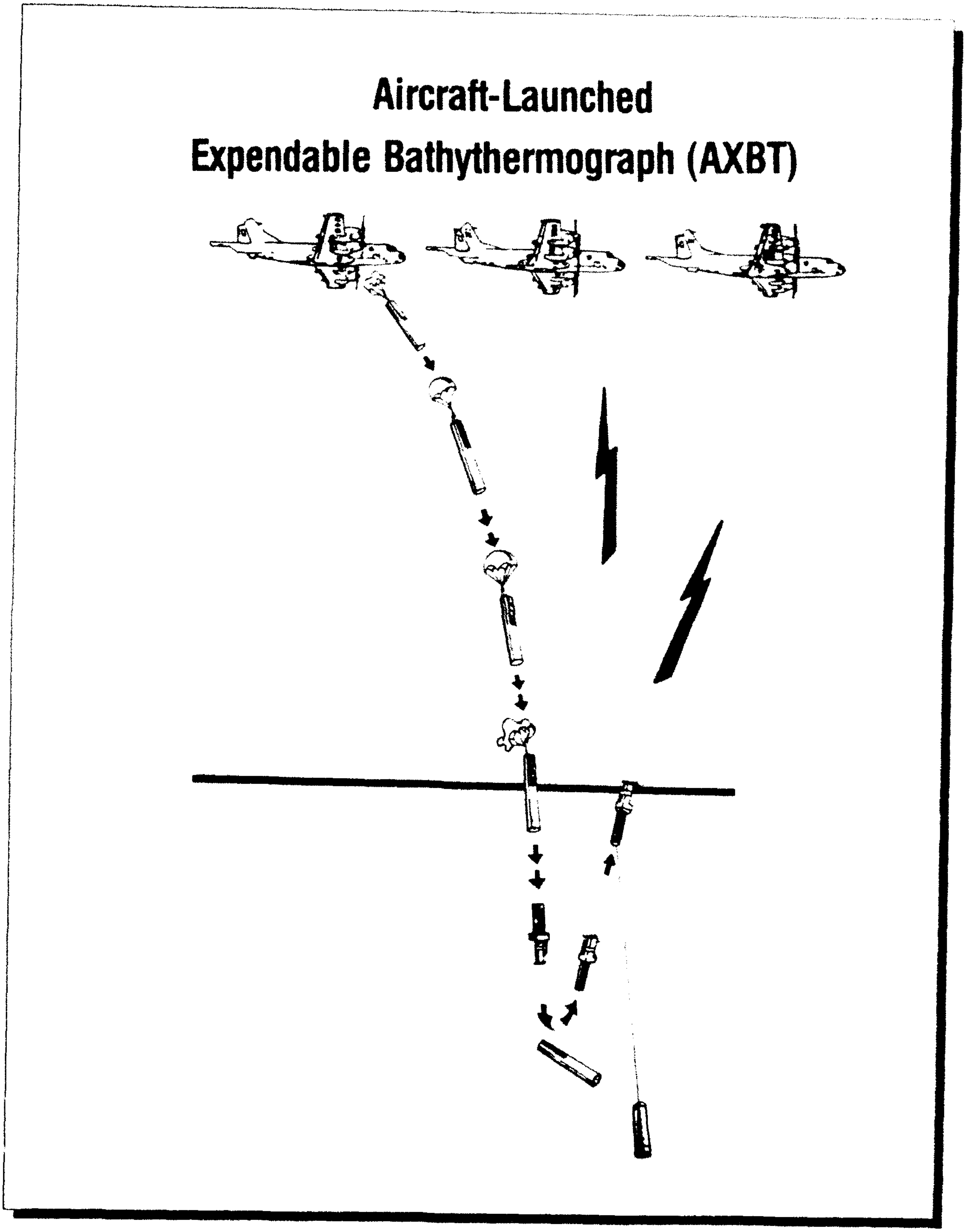


Figure D-2. Deployment of AXBT from Aircraft.

Changes in water temperature as the probe descends cause a corresponding change in the resistance of the probe's thermistor. The temperature information is converted into an audio range frequency. This frequency is transmitted up the hard wire link to the surface electronics package, where it is used to frequency modulate the transmitted carrier signal. It takes approximately 3.3 minutes for the probe to complete its 300 meter descent (approximately 8.5 minutes for the "deep" probe). About 1 minute later, the surface package scuttles itself.

The radio frequency (RF) signal from the AXBT is received on the aircraft via the aircraft's VHF-FM antenna. The audio signal from the receiver can either be analyzed in real-time using the Sippican MK-9 Data Acquisition/Processing System, or recorded on audio tapes for later playback and analysis. The MK-9 Data Acquisition/Processing System consists of a Sippican MK-9 Digital Interface and a Hewlett-Packard desktop computer. The MK-9 Digital Data Interface requires an AXBT PC board containing an RF demodulator in order to convert the AXBT's audio frequency signal.

Once the MK-9 interface is modified, the AXBT data are analyzed in the same fashion as ship-deployed XBT data. A typical AXBT 300 meter raw data file contains approximately 2,000 depth/temperature points. By selecting only those significant points which are required to reproduce the temperature profile, the number of data points is reduced to 20-30.

To prevent interference between AXBT's using the same transmission frequency, 4-5 minutes should elapse between AXBT deployments. If a finer data sampling resolution is required, AXBT's using different transmission frequencies will have to be deployed. IIP has not yet fully developed a multi-channel AXBT system, and multi-channel AXBT operations will not be addressed here.

Test Results and Discussion

The AXBT system was tested on three Coast Guard aircraft: the HH-3F helicopter; and the HC-130H (a four-engine turboprop) and HU-25A (a twin engine jet) fixed wing aircraft. The AXBT system was first tested from the HH-3F to gain experience with the equipment before testing it on the fixed wing aircraft. The primary testing was from the HC-130H, since it is IIP's primary aircraft for iceberg reconnaissance. Since the HU-25 is IIP's planned backup for the HC-130H, testing was also performed from the HU-25.

The receiving and recording equipment used for the test were loaned to International Ice Patrol by Sippican, Inc. The receiver was a single channel VHF wide band receiver. Sippican also provided sixteen AXBT's for the testing and evaluation. Sippican's support and helpful advice are gratefully acknowledged.

The AXBT data for all tests were recorded on audio cassettes for later playback and analysis. The Hewlett-Packard (HP) 85 desktop computer was used to process the AXBT data. The audio AXBT data had to be played back through the MK-9 to the HP-85 computer to be processed and analyzed. Sippican's AXBT program for the HP-85 computer was used to process the data. The time required to play back the audio recording of each AXBT drop through the MK-9, to process the data on the HP-85 computer, and to analyze the temperature profile was approximately 30 minutes per AXBT drop.

Table D-1. HH-3F Deployment Data.

Deployment #	Position	A/C Speed	Drop Altitude
1	34-07.9 N 74-44.4 W	100-120 Knots	2500 Feet
2	34-58.9 N 75-33.2 W	100-120 Knots	2500 Feet

Table D-2. HC-130H Deployment Data.

Date	Deployment #	Position	A/C Spped	Drop Altitude
Nov 18 '87	1	42-28.9 N 47-56.7 W	145 knots	2600 feet (descending)
Nov 18 '87	2	42-07.0 N 48-10.0 W	147 knots	3000 feet (ascending)
Jan 7 '88	1	35-44.8 N 73-58.1 W	155-160 knots	8000 feet (level)
Jan 7 '88	2	35-14.8 N 74-00.4 W	155-160 knots	8000 feet (level)
Jan 7 '88	3	37-16.3 N 74-14.8 W	150 knots	4500 feet (level)
Jan 7 '88	4	36-49.8 N 74-05.1 W	150 knots	8000 feet (right turn)

HH-3F Tests

Two AXBT's were deployed from an HH-3F on 16 November 1987 (Table D-1). The AXBT tests from the HH-3F were successful. A strong, clear signal was received from both AXBT's. Both AXBT's transmitted for a period of time equivalent to a complete 300 m drop. The temperature profile for the second drop was isothermal, probably because it was dropped in waters less than 300 meters, and the temperature probe simply measured the bottom temperature for the remainder of the 3.3 minute drop time.

HC-130H Tests

AXBT tests were conducted from the HC-130H on two dates, 18 November 1987 and 7 January 1988. Table D-2 summarizes the deployment information for the two dates. On 18 November, two AXBT's were deployed near Newfoundland, Canada. On the second test date, four more AXBT's were deployed off North Carolina.

The 18 November deployments from low altitudes while maneuvering were only partially successful. A clear signal was initially received from each AXBT, but static noise soon began to interrupt the AXBT signal. This interference eventually caused a premature signal loss. As a result, neither temperature profile could be read after 60-80 m.

There are four possible causes of the observed signal loss: (1) premature scuttling of the AXBT surface transmitter; (2) high sea state; (3) loss of line-of-sight between the AXBT transmitter and the aircraft receiver; and (4) wire break. Since the aircraft was maneuvering at low altitudes and numerous white caps could be observed on the sea surface, any one of these could have caused the signal loss on 18 November. The second HC-130H test (7 January) sought to determine the cause of the premature signal loss.

Before the actual testing, avionics technicians from Coast Guard Air Station Elizabeth City, North Carolina, conducted bench testing of the VHF receiver and cassette recorder. The results showed that the receiver was sensitive enough to receive the AXBT signal; the receiver and the aircraft VHF-FM antenna were compatible; and the receiver's audio output was large enough for the for the audio signal to be recorded on tape. In short, the bench testing on the ground indicated the AXBT receiver and recorder should work on the HC-130.

On 7 January, four AXBT's were deployed over a three hour period during an operational Coast Guard flight. All four deployments were successful. Good signals were received from all four AXBT's. All AXBT's transmitted for a period of time equivalent to a complete 300 meter drop. The data from deployment 2 had some interference towards the end of the drop. Deployments 1 and 2 were both done from 8000 feet, but the aircraft increased speed to 250 knots after the AXBT was deployed on deployment 2. At this speed, the aircraft was 5 nm farther from the AXBT than at 150 knots after three minutes. At first, this does not sound like a significant difference. Relatively speaking, however, the aircraft was 40 percent farther from the AXBT at 250 knots than at 150 knots after three minutes.

Deployments 3 and 4 occurred over 2 hours after deployments 1 and 2. The entire data record from deployments 3 (at 4500 feet) and 4 (at 8000 feet) was noisier than either of the previous deployments from 8000 feet. The increase in noise in the temperature profile from these two deployments might have been caused by increased sea state from a coastal storm which was moving into the drop area.

HU-25 Testing

Tests were conducted from the HU-25 on 22 December and 21 January 1988. Four AXBT's were deployed on 22 December. Due to a problem with the cassette recorder recording the AXBT data, the data from this test were not recoverable for later playback and analysis. It was later learned that the cassette recorder was temperature sensitive. Changes in temperature caused the recorder's tape speed to change. Without a frequency standard introduced at the time of recording, the recorded data were not recoverable.

Table D-3. HU-25 Deployment Data.

Date	Deployment #	Position	A/C Speed	Drop Altitude
Jan 21 '88	1	42-57 N 69-51 W	140 Knots	8000 feet (level flight)
Jan 21 '88	2	43-00.2 N 69-34.6 W	140 Knots	5000 feet (level flight)
Jan 21 '88	3	43-12.4 N 69-32.5 W	140 Knots	8000 feet (right turn)

Three AXBT's were successfully deployed on 21 January (Table D-3). All three AXBT's transmitted for a period of time equivalent to a complete 300 meter drop. All three AXBT's were deployed in waters less than 300 meters, and the temperature probe again simply measured the bottom temperature for the remainder of the 3.3 minute drop time. However, the goal of the test was to determine the ability to receive data on the airdrop, not to measure the temperature.

Operational Use of AXBT's during the 1988 IIP Season

Based on the results of the testing, the International Ice Patrol purchased and assembled its own AXBT system. It consisted of three single frequency VHF wide band receivers, a Sippican MK-9 Digital Data Interface with the RF demodulator board for AXBT operations, audio cassette recorders, and an HP-85 desktop computer. The AXBT data would be recorded on audio cassettes on the aircraft for later playback and analysis on the ground.

Twelve AXBT's (Table D-4) were deployed from IIP HC-130's in May and June 1988 on the Grand Banks of Newfoundland during ice reconnaissance flights. After each flight, the audio recording of each AXBT drop was played back through the MK-9 and processed using the HP-85 computer. Sippican's AXBT computer program was again used to process the data. After processing, the digital AXBT data were recorded on magnetic tape. From the digital recording, a series of expanded temperature plots were obtained. IIP personnel manually determined the significant (inflection) points from the AXBT paper trace. Again, it took about 30 minutes to playback, process, and analyze each AXBT. The significant point analysis was finally telecopied from Newfoundland to the IIP Operations Center in Groton, Connecticut, where a JJXX Bathythermograph message was prepared and transmitted to the Meteorological and Oceanographic Center (METOC) in Halifax, Canada; the Naval Eastern Oceanographic Center (NEOC) in Norfolk, Virginia; and the Fleet Numerical Oceanography Center (FNOC) in Monterey, California. Figure D-3 is a graphic depiction of the data flow.

Table D-4. HC-130H AXBT Deployments during 1988 IIP Season.

Date	Deployment #	Position	A/C Speed	Altitude
May 3	1	46-15 N 46-05 W	150 knots	8000 feet
May 3	2	46-15 N 46-35 W	150 knots	8000 feet
May 3	3	46-15 N 47-00 W	150 knots	8000 feet
May 18	1	43-00 N 49-41 W	150 knots	2000-2500 feet (level flight)
May 18	2	43-00 N 48-30 W	150 knots	2000-2500 feet (level flight)
May 18	3	43-00 N 47-29 W	150 knots	2000-2500 feet (left turn)
Jun 4	1	42-15 N 47-00 W	150 knots	8000 feet
Jun 4	2	42-15 N 47-40 W	150 knots	8000 feet
Jun 4	3	42-15 N 48-20 W	150 knots	8000 feet
Jun 4	4	42-15 N 49-00 W	150 knots	8000 feet
Jun 4	5	42-15 N 50-00 W	150 knots	8000 feet
Jun 4	6	42-15 N 50-59 W	150 knots	8000 feet

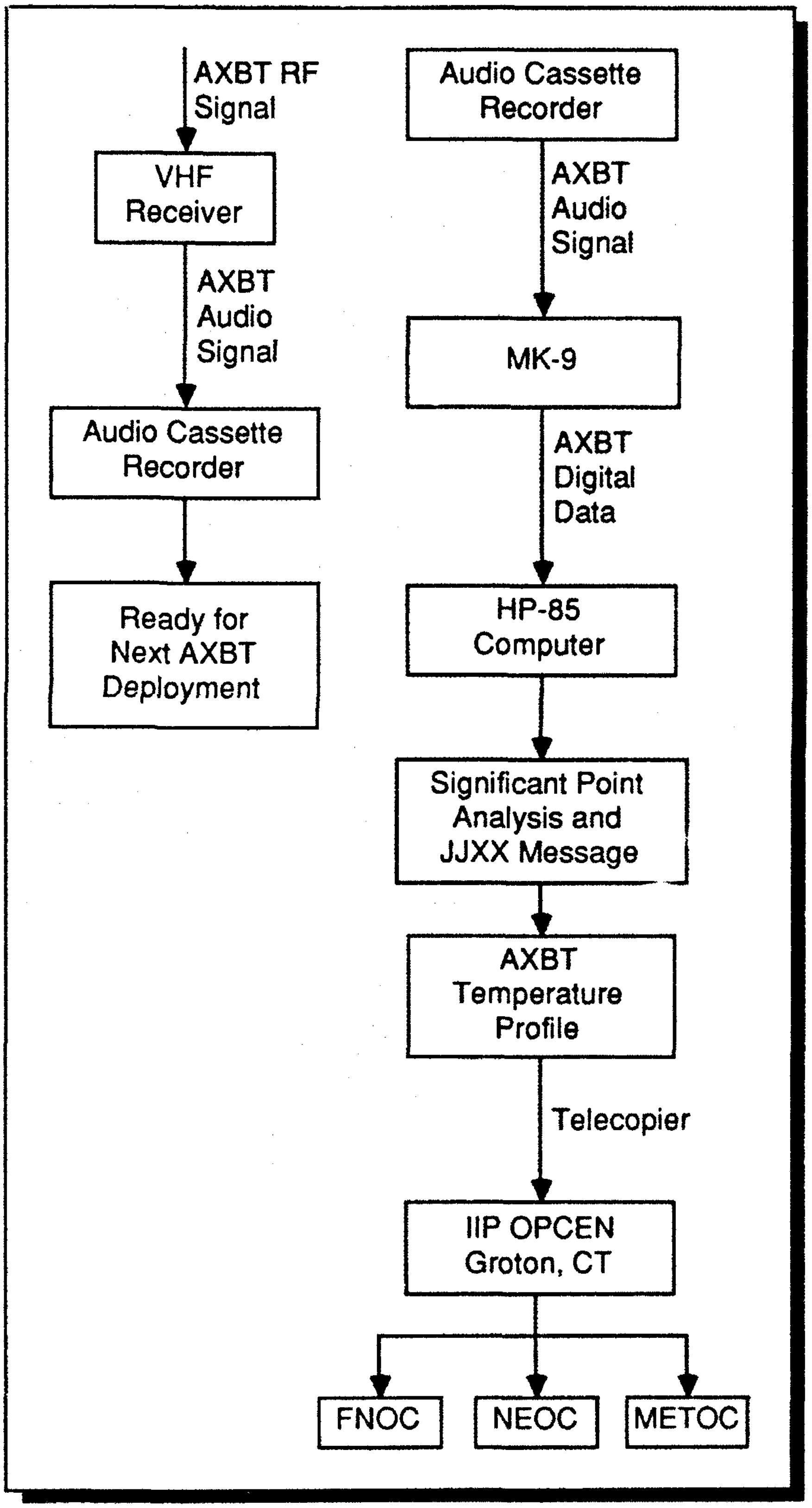


Figure D-3. AXBT Data Flow.

Typical temperature profiles from the deployments are shown in Figures D-4 through D-7. There is a great variation in the quality of the temperature profiles from the twelve AXBT's. The profiles from the three AXBT's deployed on 3 May 1988 were of the best quality (Figure D-4). All three temperature profiles had some spikes in the profile, and the frequency of spikes increased with depth (time). There were many white caps observed on the sea surface when the AXBT's were deployed.

The quality of the temperature profiles from the three AXBT's deployed on 18 May 1983 was very poor (Figure D-5). These AXBT's were deployed from a relatively low altitude (2000-2500 feet). The temperature profiles were, overall, much noisier than the temperature profiles from 3 May, despite the fact that the sea conditions were much calmer on 18 May than 3 May. Static noise interference made the temperature profiles unreadable after 170-250 meters. The temperature profile which was readable down to 250 meters (deployment 3) was from an AXBT deployed at the end of a search leg and shortly before a turn.

The six AXBT's deployed on 4 June exhibited a wide variation in quality of performance, although the deployment altitude and sea conditions were constant throughout (Figures D-6 and D-7). All six temperature profiles were in general noisier than the temperature profiles of the AXBT's deployed on 3 May, which were also deployed from 8000 feet, although the sea conditions were much calmer on 4 June than on 3 May.

Conclusions

- AXBT's are an excellent means of gathering ocean temperature information at a relatively low cost to the U. S. Coast Guard and IIP.

- AXBT data can successfully be collected using a portable, low cost, easy to operate, commercially available system such as the one presented here.

- IIP can conduct AXBT operations from either the HC-130 or HU-25 without airframe modifications.

- Optimum AXBT drop conditions are 4000-8000 feet and 150 knots. The aircraft should maintain 150 knots for the entire 3.3 minute drop time.

- If local weather conditions dictate dropping at other than optimum conditions, the following guidelines should be used in making a drop decision:

  a. As altitude decreases or aircraft speed increases, the quality of the AXBT temperature profile decreases, particularly towards the end of the profile.

  b. A drop from 3000 feet, at 150 knots, and on a steady heading will be unreadable after 150 meters. If the aircraft turns or circles around the drop site after a drop from 3000 feet, the temperature profile will be readable to 200-250 meters, or the amount of data gathered is essentially doubled.

- The quality of the temperature profile decreases with increasing sea state.

- The quality of the temperature profile decreases with time (depth) because the distance between the aircraft and AXBT increases.

- The loss of quality at low altitudes and at distance from the AXBT is due to poor transmission angle. A loss of line of sight occurs more frequently at low transmission angles due to wave and swell action, particularly in high sea states. This causes interference of the AXBT signal and spiking in the temperature profile.

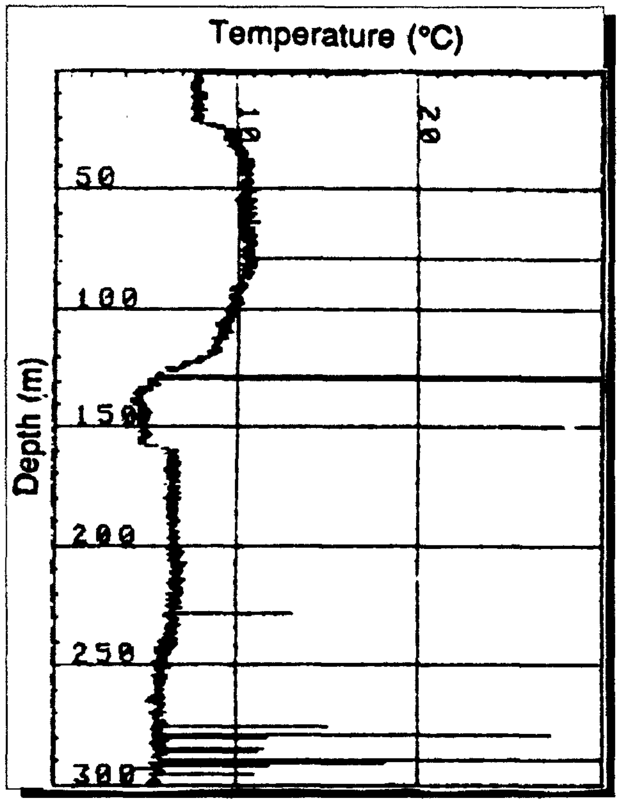


Figure D-4. HC-130 Deployment 1
May 3, 1988.

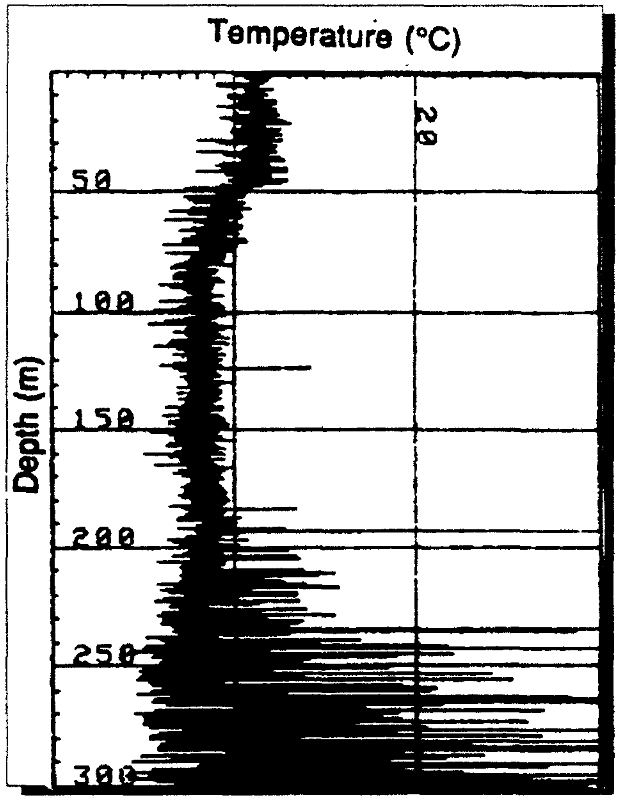


Figure D-5. HC-130 Deployment 2
May 18, 1988.

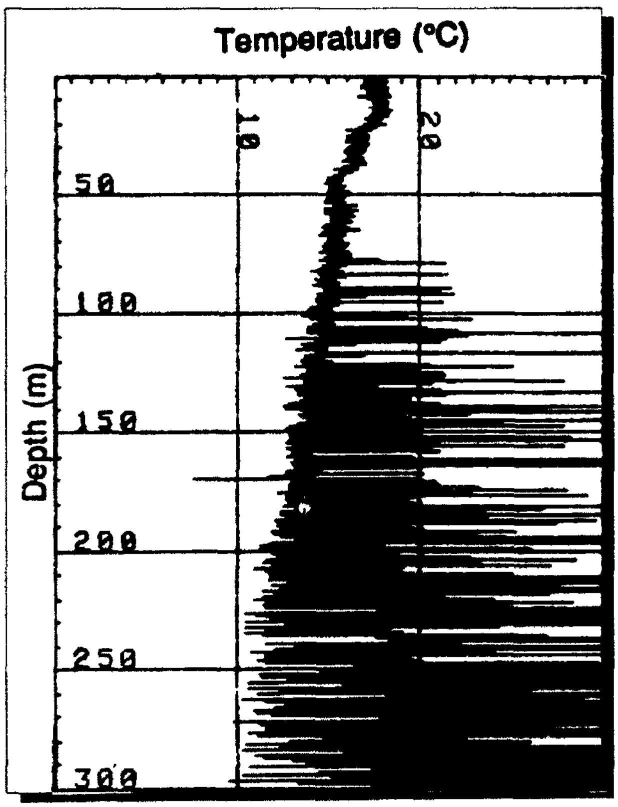


Figure D-6. HC-130 Deployment 1
June 4, 1988.

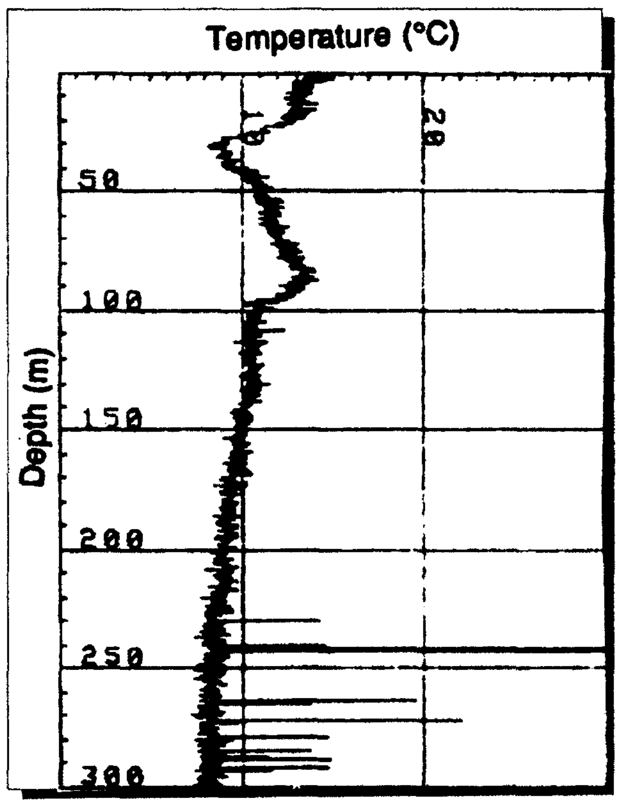


Figure D-7. HC-130 Deployment 6
June 4, 1988.

• Some of the interference or poor signal reception may be due to antenna location on the HC-130. The AXBT signal may be getting interfered with too easily by having the antenna on the far right side of the aircraft fuselage.

• The data analysis method of recording the AXBT data on audio cassettes for later playback and analysis might have worked for testing of the AXBT system, but will not be adequate for routine AXBT operations. The present method is too cumbersome and it takes too long. There is a risk of losing data due to cassette recorder malfunction, as happened during the first HU-25 test. Temperature changes or power fluctuations can affect the reliability of the cassette recorder, which in turn can affect the data.

• Recording the audio AXBT data on audio cassettes also adversely affects the quality of the temperature profile. Recording the audio signal introduces high frequency noise which results in the temperature trace being 0.5-1° C wide. Recording the AXBT in digital form would eliminate this high frequency noise, and improve the quality of the temperature profile.

Future Plans

For the 1989 International Ice Patrol Season, IIP plans the following:

• Developing an AXBT system which processes the data real-time, and records the digital data on computer floppy disk with an audio tape recorder back-up.

• Developing a program to recall the recorded AXBT data, display it on the computer screen, and manually determine the significant points from the AXBT trace displayed on the screen.

• Since the AXBT information is useful to other U.S. and Canadian users, pursuing cooperative funding from these users. IIP would provide the airframe with an AXBT system, the user would provide the AXBT's, and IIP and the users would share the data.

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Appendix E

International Ice Patrol's Side-Looking Airborne Radar Experiment (SLAREX) 1988

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Abstract

During the period 7 through 16 June 1988, the International Ice Patrol conducted an evaluation of the AN/APS-131 Side-Looking Airborne Radar (SLAR). This SLAR, installed as part of the multi-sensor surveillance AIREYE system onboard the U. S. Coast Guard HU-25B medium endurance aircraft, was evaluated for its ability to detect icebergs. The data collection occurred in an iceberg infested area off the coast of Newfoundland, Canada.

The fundamental goal of this research was to provide guidance on the ability of the AIREYE-equipped HU-25B to perform the iceberg detection mission of the International Ice Patrol. Specifically, there were two objectives:

1. Determine the optimum altitude for iceberg reconnaissance, and predict the probability of detection as a function of sea state, lateral range, and iceberg size.

2. Compare the iceberg detection capability of the AN/APS-131 SLAR with the AN/APS-135 SLAR currently used on the International Ice Patrol's HC-130 long range reconnaissance aircraft.

Ground truth (i.e. iceberg dimensions and positions, and environmental conditions) were collected by the U. S. Coast Guard icebreaker NORTHWIND (WAGB 282). The HU-25 and HC-130 aircraft flew a box pattern around the iceberg search area. Several different altitudes were used.

The Ice Branch of the Atmospheric Environment Service of Canada also had two of its SLAR-equipped ice reconnaissance aircraft (an Electra and a Dash-7) participate in the experiment.

Results indicate the AN/APS-131, while not having the azimuth resolution of the AN/APS-135, is capable of performing the iceberg reconnaissance mission. These preliminary results indicate an altitude of 4000 to 6000 feet is best for the AN/APS-131 for this mission.

Current plans for the 1989 iceberg season are for the HU-25B to complement the HC-130H reconnaissance aircraft. Due to its limited endurance, the HU-25B aircraft will not be able to replace the longer-range HC-130. However, during certain times of the year and in certain light ice years, the HU-25B should be able to conduct the International Ice Patrol mission.

Introduction

After the sinking of the RMS TITANIC on April 14-15, 1912, an International Ice Patrol Service was created to monitor the presence of icebergs near the Grand Banks of Newfoundland, and to warn mariners of these hazards. The International Ice Patrol (IIP), a unit of the U. S. Coast Guard, has provided this service since its initiation in 1914. From 1914 to 1945, IIP used visual reconnaissance from ships to monitor the icebergs. After World War II, and up to 1983, IIP used aircraft visual reconnaissance as its primary method of iceberg detection. Since 1983, IIP has utilized a Motorola AN/APS-135 Side-Looking Airborne Radar (SLAR) onboard HC-130H Hercules long-range aircraft as its primary method of iceberg reconnaissance.

In 1983, the U. S. Coast Guard installed the Motorola AN/APS-131 SLAR as part of the airborne multi-sensor surveillance AIREYE system on its HU-25B Falcon medium- range aircraft. The AN/APS-131 SLAR is very similar to the AN/APS-135 SLAR on the HC-130, except that the antenna length of the APS-131 is half that of the APS-135. This results in the APS-131 having a lower azimuth resolution than the APS-135. Although the iceberg detection ability of the APS-135 SLAR has been previously evaluated, no evaluation of the iceberg detection ability of the APS-131 SLAR has been made.

The AIREYE system on the HU-25B contains other sensors in addition to the SLAR, and are all connected by a computerized multipurpose display system. The AIREYE system has a dry film processor, as does the HC-130H. This film was the object of evaluation.

This report presents the results of an evaluation of the AN/APS-131 SLAR to detect icebergs. This evaluation was conducted by IIP from 7 to 16 June 1988 in the North Atlantic Ocean off Newfoundland, Canada. The fundamental goal of this research was to provide guidance on the ability of the AIREYE-equipped HU-25B to perform the iceberg detection mission of the International Ice Patrol. Specifically, there were two objectives:

1. Determine the best altitude for iceberg searches, and predict the probability of iceberg detection as a function of sea state, lateral range, and iceberg size.

2. Compare the iceberg detection capability of the APS-131 SLAR with the APS-135 SLAR.

This report will also compare the results of this evaluation with the results of two previous SLAR iceberg detection evaluations.

Background

Previous SLAR Studies

Two previous SLAR studies have been conducted to evaluate the ability of the AN/APS-135 SLAR to detect icebergs. During April 1984, BERGSEARCH '84 was conducted to evaluate the ability of three SLARs and two Synthetic Aperture Radars (SAR) to detect small icebergs and growlers. The M/V POLARIS provided surface truth data. Results of the data analysis reported in Rossiter et al (1985) show greater detectability is obtained with lower sea states, at lower altitudes within the operating envelope of each system, and when viewing targets across rather than up or down wind and sea. BERGSEARCH '84 data also demonstrated that ships and iceberg targets generally do not have different SLAR signatures.

The 1985 SLAR Detection Experiment was designed to determine SLAR's ability to detect various search and rescue and iceberg targets at all ranges out to 27 nm (50 km). The iceberg detection results reported in Robe et al (1985) indicate medium icebergs are detectable nearly 100% of the time in up to 2 m seas, small icebergs are easier to detect at lower altitudes and with a smaller swath width, and growlers are detectable more than 90% of the time in seas less than 1 m. Also, both growlers and small icebergs in seas less than 1 m appear to be just as detectable at lateral ranges between 25 and 50 km as they are at ranges less than 25 km. Finally, they noted similar iceberg detection performance of the AN/APS-135 SLAR in this experiment and in BERGSEARCH '84.

Description of Aircraft

A Coast Guard HC-130H and HU-25B were the two U.S. aircraft used in the experiment. The HC-130H is a long-range four engine turboprop reconnaissance aircraft, whereas the HU-25B is a medium-range twin engine fan jet aircraft. CG-1503 from Coast Guard Air Station Elizabeth City, North Carolina, was the HC-130H aircraft in the experiment, and CG-2103 from Coast Guard Air Station Cape Cod, Massachusetts, was the HU-25B. Table E-1 lists the operating characteristics of the two aircraft.

Table E-1. Aircraft Operating Characteristics.

Aircraft	HC-130H	HU-25B
Patrol Altitude	4-10,000 ft	4-10,000 ft
Patrol Speed	180-250 kt	180-250 kt
Endurance	$<$7.5 hr	$<$3 hr
Navigation	INS (LTN-72)	AIRNAV (INS & LORAN)
Drop Capable	Yes (Incl TOD)	Yes (Incl mini-TOD)

Description of AN/APS-135 and AN/APS-131 SLAR

Significant system parameters of each SLAR are presented in Table E-2. The major difference between the two systems is the antenna length of each. The APS-135 has a 4.8 m long antenna, while the APS-131's antenna is 2.4 m long. This results in the APS-131 having one-half the azimuth resolution of the APS-135.

Description of Targets

The USCGC NORTHWIND was the only surface vessel used as a SLAR target during the evaluation. The NORTHWIND is a U.S. Coast Guard wind-class icebreaker, and is 81 m long and 19 m wide.

IIP classifies icebergs into five size categories: growler, small, medium, large, and very large. Table E-3 lists IIP's length and height parameters for each size category. A total of 44 icebergs were used as targets during the evaluation, consisting of 13 small, 27 medium, and 4 large icebergs. No growlers or very large icebergs were used.

Table E-2. SLAR Operating Parameters.

Aircraft	HC-130H	HU-25B
SLAR (Real Aperture)	Motorola AN/APS-135	Motorola AN/APS-131
Frequency	X-Band (9250 MHz)	X-Band (9250 MHz)
Peak Power	200 Kw	200 Kw
Pulse Width	[illegible]	[illegible]
Antenna Characteristics		
Length	4.8 m	2.4 m
Polarization	VV	VV
Elevation Coverage	-1.5 to -45 deg	-1.5 to -45 deg
Depression Angle	1.5 deg	1.5 deg
Azimuth Resolution	0.47 deg	0.8deg
Range Resolution	30 m	30 m
Receiver Bandwidth	6 MHz	6 MHz
Swath Widths	25,50,100,150 km	25,50,100,150 km
Look Direction	L & R	L & R
Data Format	Negative Film	Negative Film VHS video tape

Table E-3. IIP Iceberg Size Categories.

Descriptive Name	Height (m)	Length (m)
Growler	<5	<15
Small Iceberg	5-15	16-60
Medium Iceberg	16-45	61-122
Large Iceberg	46-75	123-213
Very Large Iceberg	>75	>213

Table E-4. Range of Parameters.

Aircraft	Target	Lateral Range (nm)	Search Altitudes (ft)	Significant Wave Height (m)	Wind Speed (m/sec)	Range Scales (nm)
HC-130H (APS-135)	Northwind	2-27	4,000 6,000 8,000 10,000	1-2.7	7.2-17.5	27
	Icebergs	2-27	4,000 6,000 8,000 10,000	1-2.7	7.2-17.5	27
HU-25B (APS-131)	Northwind	2-50	4,000 5,000 6,000 8,000 10,000	0.3-2.7	3.1-17.5	27 54
	Icebergs	2-50	4,000 5,000 6,000 8,000 10,000	0.3-2.7	3.1-17.5	27 54

Description of Environmental Conditions

Seas were 1-2 meters during most of the experiment. Table E-4 lists the range of environmental and operating parameters observed and used during the experiment.

Data Collection Procedures

General

Data for this evaluation were collected on 7-16 June 1988. The exact location of data collection varied with ice movement within a box bounded by 51° N to 52° N and 52°30' W to 53°30' W (Figure E-1). Each evening, IIP personnel on USCGC NORTHWIND were responsible for selecting the next day's area of study around a group of iceberg targets, and passing the study area coordinates to the aircraft using VHF radio prior to the aircraft's departure. The next morning, the aircraft would confirm the location of NORTHWIND, and the study area, after takeoff.

During the data collection runs, the IIP crew on NORTHWIND monitored the positions of each iceberg in the study group, and recorded surface environmental data.

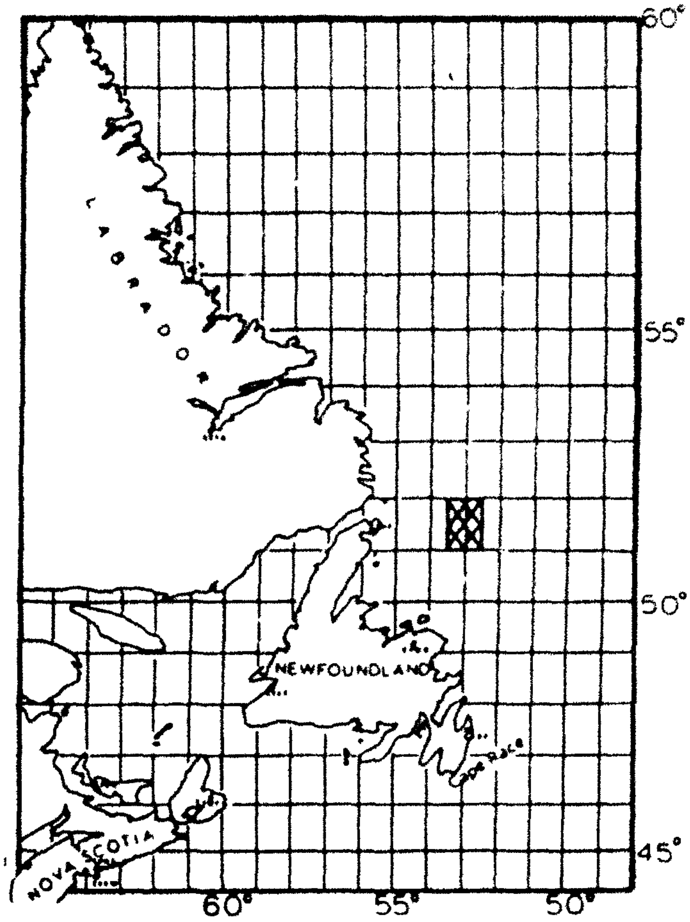

Figure E-1. Cross-Hatched Area Depicts SLAREX '89 Study Area

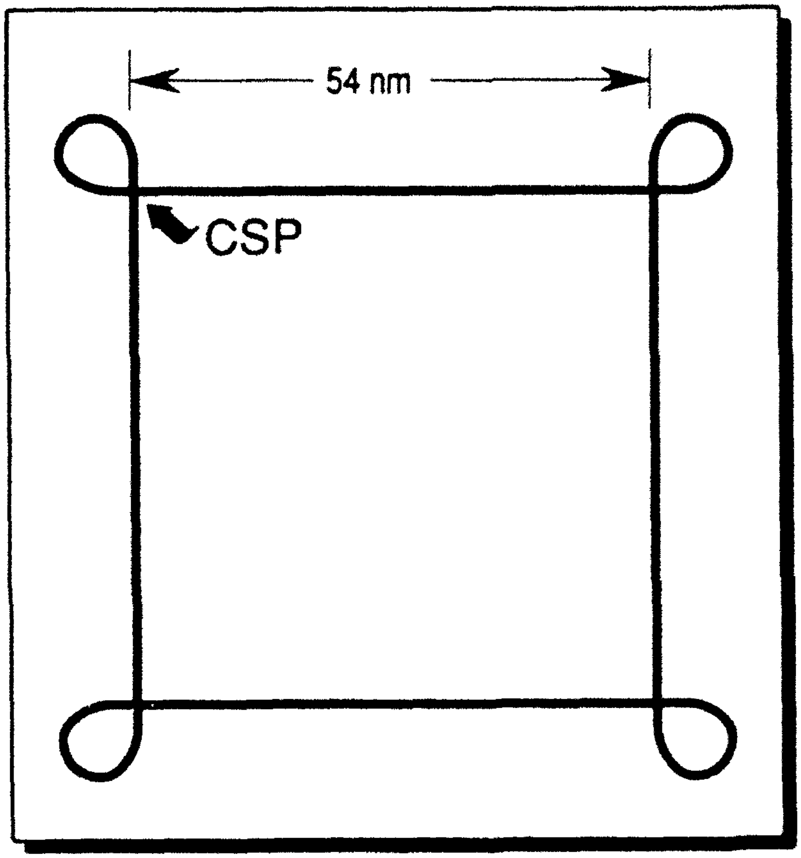

Figure E-2. TYPE 1 Search Pattern. CSP is Commerce Search Point.

Search Patterns

Two search patterns were used by the aircraft during the evaluation. Most of the searches were an area (type 1) search consisting of a square with 54 nm (100 km) sides (Figure E-2). Both the HU-25B and HC-130H flew this pattern at four altitudes: 4000, 6000, 8000, and 10,000 feet. All these searches were conducted using the 27 nm (50 km) range scale on the SLAR.

Only the HU-25B flew the second search pattern. It was a parallel line (type 2) search (Figure E-3). This pattern was flown at 4000 and 8000 feet. The track spacing was 6 nm (11 km) for the first three legs, and 12 nm (22 km) for the last two legs. Both the 27 nm (50 km) and 54 nm (100 km) range scale on the SLAR were used on this pattern. Because of the limited amount of data collected with the 54 nm scale, no discussion on the use of this scale for ice reconnaissance will be made in this report.

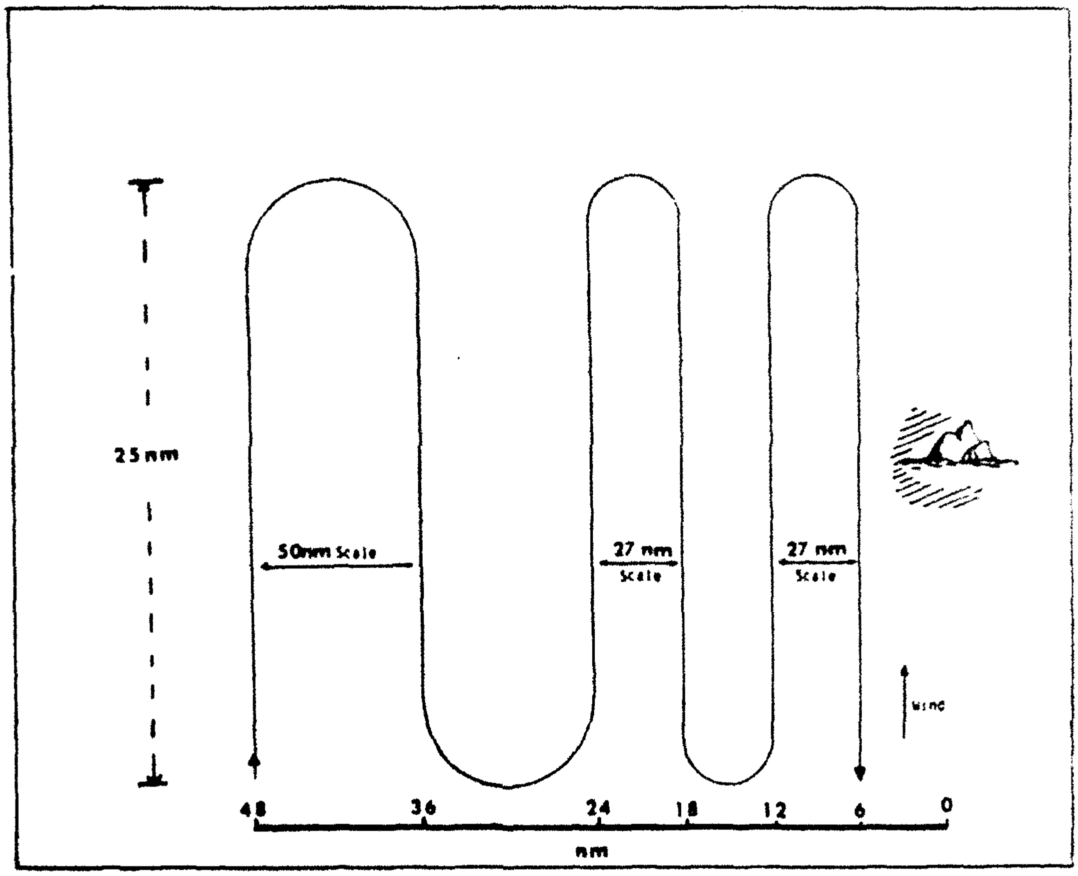

Figure E-3. Type 2 Search Pattern.

Table E-5 lists the pattern and altitude each aircraft flew for each day of the experiment.

SLAR Data Format

The output analog imagery from both the APS-131 and APS-135 SLAR was recorded on 23 cm wide dry-process film. The HU-25B also used a video recorder to record the analog imagery on VHS tape format.

Two logs were maintained on the aircraft to aid the data analysis. The SLAR Search Run Summary Sheets recorded the start and stop time of each leg; aircraft speed, altitude, and heading; and SLAR settings. The second was a SLAR Target Log to record latitude, longitude, and time of each SLAR target observed by the SLAR operator, as well as the SLAR operator's interpretation of the SLAR target (ship or iceberg, and iceberg size). The SLAR operator also circled the target on the SLAR film, and annotated the film with the target number from the SLAR Target Log.

Table E-5. Aircraft Search Pattern.

Date	Aircraft	Search Pattern	Altitude (ft)	Number of Sorties
8 June	HC-130	1	8000	2
	HU-25	1	6000	1
9 June	HC-130	1	4000	2
	HC-130	1	6000	2
	HC-130	1	10,000	2
	HU-25	1	6000	2
10 June	HU-25	1	8000	2
	HU-25	1	4000	2
11 June	HU-25	1	10,000	2
	HU-25	1	8000	2
12 June	HU-25	1	4000	2
	HU-25	1	5000	2
	HC-130	1	4000	2
	HC-130	1	6000	2
	HC-130	1	8000	2
	HC-130	1	10,000	2
13 June	HU-25	2	8000	4
	HU-25	2	4000	2
15 June	HU-25	1	6000	2
	HU-25	1	8000	1
	HU-25	1	10,000	1

Table E-6. Total Detection Opportunities
(Type 1 and Type 2 Searches, 27 and 54 nm Scales)

	HU-25B (APS-131)	HC-130H (APS-135)
S	133	48
M	230	132
L	45	17
Northwind	76	31
Total	484	228

Surface Truth Data

Every 15 minutes, IIP personnel on USCGC NORTHWIND recorded NORTHWIND's position and, bearing and range to every visible ice target in the SLAR Target Position Record. Position data were obtained from a GPS/ LORAN C receiver. The bearing and range data were obtained from NORTHWIND's surface search radar. Every 30 minutes, IIP personnel recorded surface environmental conditions, including wind speed/direction, cloud cover, visibility, sea state, humidity, and air and water temperature.

Post-Analysis

Following the experiment, IIP personnel used the SLAR film, SLAR Search Run Summary Sheets, SLAR Target Logs, and SLAR Target Position Records to reconstruct and describe each target detection opportunity. The IIP analysts correlated the SLAR Target Position Records with the SLAR film to determine which of the documented targets were discernible on the film.

Results and Discussion

Table E-6 summarizes the total number of detection opportunities for each SLAR. Table E-7 shows the distribution of the detection opportunities with altitude and lateral range for each SLAR. For the APS-135, the detection opportunities were distributed evenly between the four altitudes 4,000, 6,000, 8,000, and 10,000 feet and in the mid to far-range (5 to 27 nm). For the APS-131, most of the detection opportunities were at 4,000 and 8,000 feet and in the far range (15-27 nm).

Table E-7. Total Detection Opportunities as a Function of Alititude and Lateral Range.

HC-130H (APS-135) Total Detection Opportunities
(Type 1 Searches)

	Range (nm)					
	0-4	5-9	10-14	15-19	20-27	Total
Altitude (ft)						
4,000	1	15	14	7	18	55
5,000	0	0	0	0	0	0
6,000	0	14	12	14	20	60
8,000	0	13	8	15	17	53
10,000	0	13	13	15	19	60
12,000	0	0	0	0	0	0
Total	1	55	47	51	74	228

HU-25B (APS-131) Total Detection Opportunities
(Type 1 and Type 2 Searches)

	Range (nm)						
	0-4	5-9	10-14	15-19	20-27	27-50*	Total
Altitude (ft)							
4,000	16	27	19	31	29	0	122
5,000	0	9	2	11	11	0	33
6,000	2	16	10	17	17	0	62
8,000	8	37	39	38	52	28	202
10,000	3	1	5	10	22	0	41
12,000	0	0	0	6	0	18	24
Total	29	90	75	113	131	46	484

*27-50 nm ranges for Type 2 Searches only.

Table E-8. Probability of Detection as a Function of Iceberg Size (Type 1 and Type 2 Searches, 27 nm Scale)

	Detections/Opportunities (POD)	
	HU-25B APS-131	HC-130H APS-135
Small	114/116 (.98)	47/48 (.98)
Medium	200/203 (.96)	132/132 (1.00)
Large	36/36 (1.00)	17/17 (1.00)
Total	350/355 (.99)	196/197 (.99)
Northwind	53/53 (1.00)	31/31 (1.00)

Table E-8 lists the number of SLAR detections over the number of detection opportunities, and the probability of detection (POD), for each SLAR as a function of iceberg size (and for the NORTHWIND). The two SLARs have a very similar iceberg detection capability. The iceberg POD (for small, medium, and large icebergs) for each SLAR is 99 percent.

Table E-9 lists the iceberg POD as a function of lateral range and altitude. Again, both SLARs have a similar iceberg detection capability at all altitudes and lateral ranges. There is no significant variation in iceberg POD with lateral range or altitude. There is a small decrease in iceberg POD at 8,000 and 10,000 feet for the APS-131 SLAR, however.

These results are similar to the results obtained during BERGSEARCH '84 and the 1985 SLAR Detection Experiment, for the given type of targets and sea conditions.

Table E-9. Iceberg POD as a Function of Lateral Range and Altitude (Type 1 and 2 Searches, 27 nm Scale)

	HC-130H	HU-25B
Range (nm)	APS-135	APS-131
0-4	1/1 (1.00)	24/24 (1.00)
5-9	53/53 (1.00)	82/83 (.99)
10-14	42/42 (1.00)	62/63 (.98)
15-19	43/43 (1.00)	85/88 (.97)
20-27	57/58 (.98)	97/97 (1.00)

	HC-130H	HU-25B
Altitude (ft)	APS-135	APS-131
4,000	47/47 (1.00)	105/105 (1.00)
5,000	-	29/29 (1.00)
6,000	52/52 (1.00)	52/52 (1.00)
8,000	46/46 (1.00)	130/134 (.97)
10,000	51/52 (.98)	31/32 (.97)
12,000	-	3/3 (1.00)

Table E-10. Number of SLAR Targets Missed by SLAR Observers over Total Number of SLAR Targets

HC-130H (APS-135) Operator Misses

	Altitude (ft)				
	4,000	5,000	6,000	8,000	10,000
S	0/12		0/12	1/12	1/11
M	2/31		2/36	7/29	2/36
L	0/4		0/4	1/5	0/4
Total	2/47		2/52	9/46	3/51
Northwind	0/8		0/8	0/7	0/8

HU-25B (APS-131) Operator Misses

	Altitude (ft)				
	4,000	5,000	6,000	8,000	10,000
S	0/35	1/8	3/15	0/44	0/11
M	0/58	1/17	3/30	1/74	0/20
L	0/12	0/4	0/7	0/12	0/0
Total	0/105	2/29	6/52	1/130	0/31
Northwind	0/17	0/4	1/10	0/27	0/9

Table E-10 shows the distribution of the number of SLAR targets missed by the HC-130H and HU-25B SLAR observers over the total number of targets detected by the SLAR with altitude. Table E-11 shows the distribution of HC-130H and HU-25B SLAR operator misses with lateral range.

Although there is not enough data to draw any clear conclusions, some broad tendencies can be drawn from the data in Tables E-10 and E-11. For the HC-130H, there is an indication in Table E-10 that the SLAR observer is more likely to miss a target on the SLAR film at altitudes 8000 feet and greater than at altitudes less than 8000 feet. For the HU-25B observers, there is no clear indication at which altitude the SLAR observers are most likely to miss targets. The greatest percentage of misses was at 6000 feet, while the least percentage of misses was at 8000 feet. Table E-11 indicates that the HC-130H and HU-25B SLAR observers are more likely to miss targets at lateral ranges greater than 15 nm than at lateral ranges less than 15 nm.

Table E-11. Number of SLAR Targets Missed by SLAR Observers over Total Number of SLAR Targets.

HC-130H (APS-135) Operator Misses

	Range (nm)				
	0-4	5-9	10-14	15-19	20-27
S	0/0	0/0	0/17	2/8	0/22
M	0/1	3/37	0/24	3/35	7/35
L	0/0	1/16	0/1	0/0	0/0
Total	0/1	4/53	0/42	5/43	7/57
Northwind	0/0	0/2	0/5	0/8	0/16

HU-25B (APS-131) Operator Misses

	Range (nm)				
	0-4	5-9	10-14	15-19	20-27
S	0/12	1/20	0/19	2/28	1/35
M	1/10	1/40	0/37	0/51	3/62
L	0/2	0/22	0/6	0/6	0/0
Total	1/24	2/82	0/62	2/85	4/97
Northwind	0/5	0/7	0/9	0/17	1/29

Table E-12. HC-130H Operator Object Misinterpretations.

Number of Incorrect Object Misinterpretations
vs Total Number of SLAR Targets

	Altitude (ft)			
	4,000	6,000	8,000	10,000
S	0/12	0/12	0/12	2/11
M	1/31	0/36	1,29	2/36
L	0/4	0/4	0/5	0/4
Total	1/47	0/52	1/46	4/51
Northwind	1/8	0/8	3/7	6/8

	Range (nm)				
	0-4	5-9	10-14	15-19	20-27
S	0/0	0/0	1/17	0/8	1/22
M	0/1	1/37	0/24	1/35	2/35
L	0/0	0/16	0/1	0/0	0/0
Total	0/1	1/53	1/42	1/43	3/57
Northwind	0/0	1/2	3/5	3/8	6/16

Table E-12 lists the distribution of the number of incorrect interpretations by the HC-130H SLAR observers over the total number of SLAR targets with altitude and lateral range. This table considers only whether the target was wrongly interpreted as an iceberg or ship. Table E-13 lists the distribution of HC-130H observer misinterpretations of SLAR target size over total number of SLAR targets with altitude and lateral range. Since the HU-25B SLAR observers were inexperienced at interpreting SLAR data, they were not considered.

Again, no clear conclusions can be made from the data in Tables E-12 and E-13, but some tendencies can be seen. Tables E-12 and E-13 indicate the HC-130H observers were more likely to misinterpret the type and size of the SLAR target at altitudes 8000 feet and higher, and at lateral ranges greater than 10 nm.

In addition to the data given in Tables E-10 through E-13, the quality of the SLAR imagery from 4000 and 6000 feet seemed better than from 8000 or 10,000 feet. The imagery of ships from 4000 and 6000 feet was harder with sharp edges, making it easier to differentiate between a ship or an iceberg at these altitudes.

Table E-13. HC-130H Operator Size Misinterpretations.

Number of Incorrect Size Interpretations vs
Total Number of SLAR Targets

	Altitude (ft)			
	4,000	6,000	8,000	10,000
S	1/12	1/12	3/12	3/11
M	0/31	0/36	0/29	0/36
L	0/4	0/4	0/5	0/4
Total	1/47	1/52	3/46	3/51
Northwind	1/8	0/8	0/7	0/8

	Range (nm)				
	0-4	5-9	10-14	15-19	20-27
S	0/0	0/0	3/17	2/8	3/22
M	0/1	0/37	0/24	0/35	0/35
L	0/0	0/16	0/1	0/0	0/0
Total	0/1	0/53	3/42	2/43	3/57
Northwind	0/0	1/2	0/5	0/8	0/16

Conclusions

For the given sea conditions and size of targets, all altitudes and lateral ranges out to 27 nm appear suitable for iceberg searches. For the APS-131 SLAR, an altitude of 6,000 feet and lower appears to be a slightly better altitude for iceberg reconnaissance than 8,000 feet or higher. More study is needed at higher sea states and with smaller ice targets before any final conclusions can be drawn regarding the optimum iceberg search altitude and the POD as a function of sea state, lateral range, and iceberg size.

The APS-131 is very similar in its iceberg detection capability to the APS-135. These results indicate it is capable of performing the iceberg reconnaissance mission of the International Ice Patrol.

Current plans for the 1989 iceberg season are for the HU-25B to complement the HC-130H reconnaissance aircraft. Due to its limited endurance, the HU-25B aircraft will not be able to replace the longer-range HC-130H. However, during certain times of the year and in certain light ice years, the HU-25B should be able to conduct the International Ice Patrol mission.

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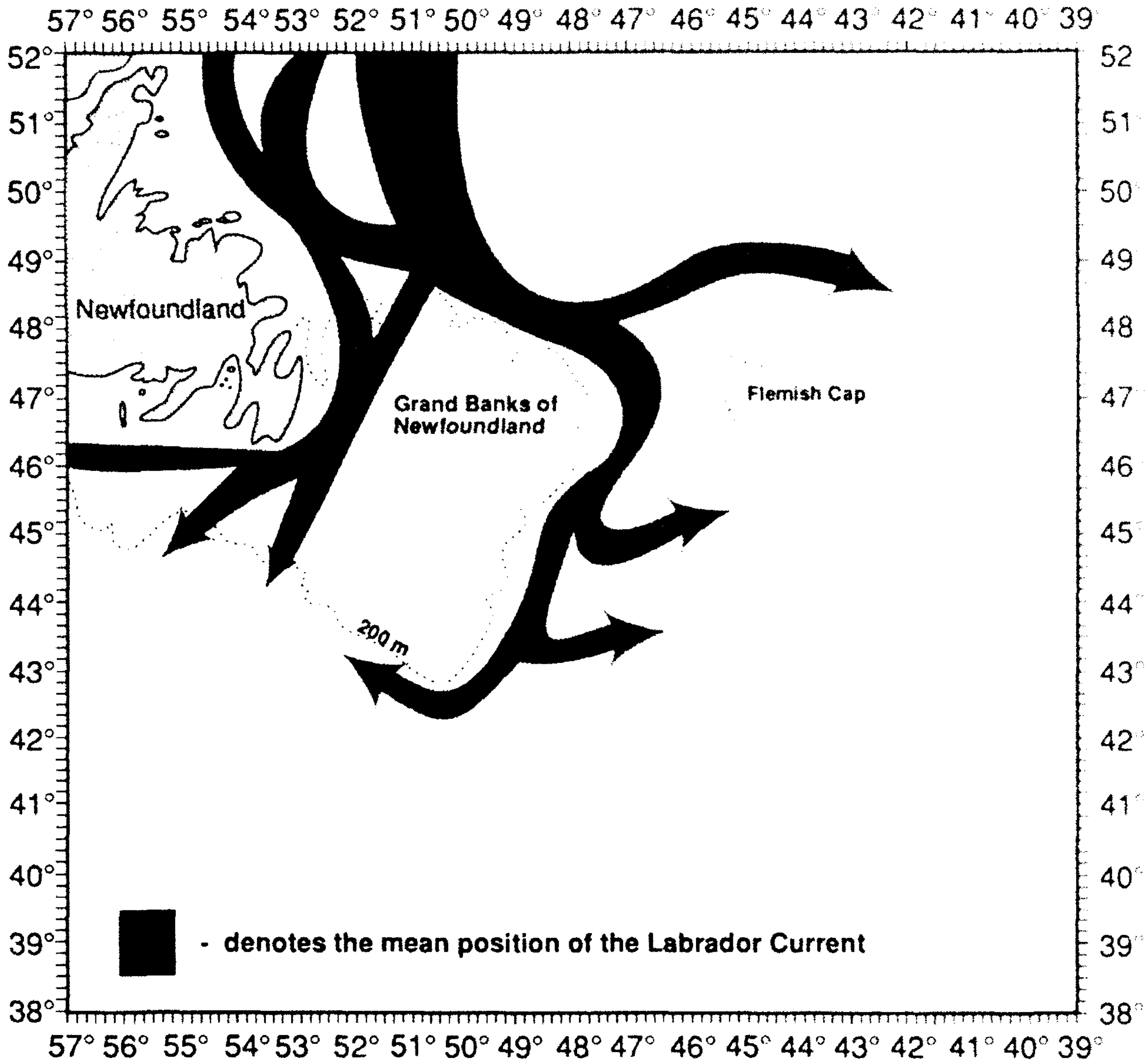

Figure 33. This figure depicts the mean position of the Labrador Current, the main mechanism for transporting icebergs south to the Grand Banks.